

Prospects for

# Research in Transport and Logistics

on a Regional – Global Perspective

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## **WORDS of WELCOME and GRATITUDE**

Stimulated by the globalization and the new economic trends, the value of global trade has been increasing twice as fast as the global production. This considerable increase in the volume and value of global trade and production must be carried and delivered by physical means. This indicates that transportation and logistics are the most promising industries for the world economy. Companies today have been offered a world of opportunities in terms of production and sales thanks to the globalization but they still need logistics in order to deliver the right product or service to the right place under proper conditions. The rise in worldwide trade and the increasing interaction between countries previously separated by trade barriers have spurred a significant increase in logistics flows at all geographical levels. Whereas virtual trade is possible virtual logistics and transportation is not.

In a study titled “Logistics Benchmarking in EU” it is underlined that the critical factors that play important role in the evolution of logistics in a country are transportation infrastructure, knowledge and communication infrastructure, transportation and logistics education potential, regulations, and effectiveness in national and international coordination. We tried to reflect the effects of such changes in the presentations of RTraL 2009. That is why, we aimed to bring together researchers and practitioners in global, regional as well as country-based perspective and stimulate the exchange of ideas in the fields of logistics and transportation as defined. The attention is given to the recent theoretical and practical developments in all related fields and the respective concepts, models and methodologies. The conference consists of research papers and application case sessions about regional and global issues in logistics and transportation, public policies, education and training, transport modeling, traffic engineering, supply chain management, transportation infrastructure and investment appraisal, transportation planning and economics, and sustainable transport policies. Particular emphasis will be given to recent developments in all related fields, their methodologies, concepts and implementation details.

In this Conference, the call for papers attracted 106 papers. The papers were reviewed by three referees using double-blind process. Among the full papers of the registered authors, 8 are rejected, 48 are accepted without revision while 50 are conditionally accepted and then revised according to the invaluable suggestions of referees. If this Conference proves to be a successful one, the contribution of the referees will be one of its most valuable assets. Therefore, RTraL 2009 Conference Organizers owe much gratitude to the members of International Program Committee for their valuable reviewing work. Special thanks are due to the keynote speaker Werner Rothengatter – University of Karlsruhe and to the panelists Eddy Van de Voorde – University of Antwerp, Ali Huzayyin – University of Cairo, Yücel Candemir – Istanbul Technical University, Werner Rothengatter – University of Karlsruhe.

We also want to draw your attention to our sponsors list. We would like to thank the sponsors of the conference for their generosity and their investment in current and future transportation and logistics researchers.

Fusun ÜLENGİN  
RTraL '09 Chair, Dogus University, Istanbul, Turkey

## INTRODUCTION

**“International Conference on Prospects for Research in Transport and Logistics on a Global – Regional Perspective”** has undertaken the challenge to host very important experts and practitioners of Transport and Logistics from a large spectrum of countries. In our opinion, the conference has fulfilled the purpose of establishing an International Society; “Eurasian and Eastern Mediterranean Institute of Transportation and Logistics Association (EMIT)” that is expected to have a very promising role in the Eurasian and Eastern Mediterranean countries. The purpose of the Association is to contribute to establishing and developing the exchange of research work between all parts of the world in all fields of transportation and logistics.

This proceedings book consists of 13 chapters, grouping the contributed papers into the following categories: Global Issues in Logistics and Transportation (3 papers), Regional Issues in Logistics and Transportation (2 papers), Education and Training in Logistics and Transportation (2 papers), Supply Chain Management (3 papers), Sustainable Transport Policies, Traffic Engineering (4 papers), Evaluation of Public Policies, Network Models and Environment (4 papers), Contemporary Topics in Transport and Logistics (7 papers), Transport Planning and Economics (3 papers), Planning, Operations, Management and Control of Transport and Logistics (3 papers), Transport Modeling (5 papers), Freight Transportation and Logistics Management (7 papers), Transport and Land Use (3 papers), Transport Infrastructure and Investment Appraisal (2 papers)

It can be readily seen from this volume of selected papers that all papers do elaborate on rather timely problems in the fields of expertise related to Transport and Logistics, which have a considerable global importance.

Füsün ÜLENGİN  
RTraL '09 Chair, Dogus University, Istanbul, Turkey

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# **Chapter 1**

Global Issues in Logistics and Transportation



Werner Rothengatter

## **Potential to Reduce GHG through Efficient Logistic Concepts**

### **Abstract**

Saving GHG is the biggest challenge of the forthcoming decades. The EU has decided to reduce CO<sub>2</sub> by 20% until 2020 (compared with 1990), if other countries follow, even by 30%. In freight transport it will be difficult to achieve such figures, because freight transport is growing faster than GDP and energy efficiency is improving only slowly. Most studies assume that energy savings in freight transport in the first instance stem from more efficient propulsion technology. But technical progress on this field will by far not achieve the ambitious targets of CO<sub>2</sub> reduction. Therefore, the logistic concepts and processes have to be analyzed with respect to their potential to contribute to CO<sub>2</sub> savings. The German Ministry of Economic Affairs has launched the project LOGOTAKT (2007) which is on developing a logistic concept to save energy and reduce climate gases of freight transport.

LOGOTAKT presents a new concept of scheduled logistic services which is organized as a virtual moving platform, serving the entry points and points of transshipment in defined time intervals. It is organized as an open network for which different companies have access and can participate. For long-haul transport railway service can be included. For this purpose a subset of marshalling yards is changed to logistic centers to bundle freight which can be decomposed into pallets on the last mile to the clients. A logistic concept will be presented which uses all of the above options. Simulation exercises show that the concept may save about one third on CO<sub>2</sub> emissions in the affine sectors which makes about 10% for the total freight transport market. This is possible in a self-financing regime without state subsidies. Together with other measures it seems to be possible to achieve CO<sub>2</sub> reduction values of 20-30% in the sector of freight transport and logistics and to meet the global EU reduction target.

# Potential to Reduce GHG through Efficient Logistic Concepts

## 1 Introduction

Saving GHG is the biggest challenge of the forthcoming decades. The EU has decided to reduce CO<sub>2</sub> by 20% until 2020 (compared with 1990), if other countries follow, even by 30%. In freight transport it will be difficult to achieve such figures, because freight transport is growing faster than GDP and energy efficiency is improving only slowly. As a result most of the CO<sub>2</sub> savings would have to be provided by better logistics concepts.

The logistic concept LOGOTAKT will be presented which is based on a virtual moving logistic platform and provides deliveries regularly on a fixed schedule. Railways are integrated, supposing that major marshalling yards can offer high level logistic facilities for to consolidate large consignments from pallet units. The time table of the moving platform might be adjusted to the frequency and volumes of delivery. Simulated tests are run on a 6, 12 and 24 hrs schedule which seems to meet the requirements of many shippers on long-haul relationships.

The paper will elaborate furthermore on the institutional requirements for an open network to bring logistic alliances together, the potential transaction cost and the problems of privacy. It will come out with the conclusion that better logistic concepts can contribute more than 10% savings of energy/CO<sub>2</sub> and that the challenge to reduce 20-30% of CO<sub>2</sub> emissions in freight transport until 2020 is not unrealistic, at least for the key segments of the market. This is underlined by reporting on voluntary actions of the industry, e.g. DHL has announced to reduce the CO<sub>2</sub> emissions by 30% until 2020. If this is possible in the most complex market of parcel service then it should also be possible in market segments with more simple operations, planning and management.

## 2 Contribution of Freight Transport to Global Warming

The transport sector is responsible for 24% of the world-wide CO<sub>2</sub>-emissions. In the OECD countries this share has already grown to 30% and a further increase is highly probable.

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### **Figure 1: Development of CO2 Emissions in OECD Countries by Sector**

Source: ECMT, 2007

Figure 1 shows that the emissions of freight transport in OECD countries are about on third of the total transport emissions and that road freight emissions are increasing at a higher speed compared with the emissions of road passengers. Reason is that the growth of passenger transport is tending towards a saturation level in industrialized countries (declining population, modest growth of income for low and middle income classes). Furthermore the rising energy prices have revealed a high technological potential for fuel savings (smaller, lighter, energy efficient cars), i.e., a trend towards less powered cars and a reduction of SUV sales can be observed.

It can also be concluded from the Figure that rail and inland waterway shipping do not play a dominant role in land-borne freight transport. Reasons are (1) the low share of the freight transport market which is held by the railways, and (2) the comparatively low emissions of CO<sub>2</sub> per tonkm of transport which is about 15-30% of the specific emissions of road freight transport, on the average (see INFRAS/IWW, 2004).

When it comes to freight transport the potential for energy savings appear much lower compared with passenger transport. Reasons are:

- Firms plan their logistics by and large efficiently,
- Firms buy the vehicles according to economic advantages (not according to prestige arguments as in the case of passenger car purchase),
- Energy is a cost factor and the industry will try to develop least cost strategies for energy consumption,
- The growth rate of freight transport (in terms of tonkm) is much higher than in passenger transport. In the last decades it was higher than the growth rate of GDP in the OECD countries.

Therefore, a stabilization of CO<sub>2</sub> emissions of freight is already regarded a success in the literature and the EU Commission is expecting only a modest contribution to CO<sub>2</sub> reduction, much lower than the targeted average of 20% to 30% until 2020 compared with 1990.

### **3 Elements of a CO<sub>2</sub> Reduction Strategy in Freight Transport**

#### **General Action List**

The most important elements of more intelligent logistics are (see EC, 2008; German MoT, 2008; Manheim, 1999):

##### **(1) Use of better technology, modern engines with less fuel consumption**

Until now the improvements of environmental quality in freight transport has focused on toxic exhaust emissions (NO<sub>x</sub>, Particles) and noise reduction. This reflects in a rising share of EURO 4 and EURO 5 trucks on the highways. Parts of EURO 6 technology (particle filters or traps) are already on the market although EURO 6 is not yet defined. But there is little progress with the reduction of fuel consumption. More technical intelligence was invested in the increase of horsepower to keep speed high in mountainous areas. Presently there is no specific action at sight within the EU or some of the member countries which could be considered comparable to the effort on the side of passenger cars (120 g/km limit planned, to be enforced by a penalty system). As fuel consumption is an important factor in competition, because the share of fuel costs has increased drastically in the past years, one can assume that the potential of fuel savings through better technology will not be very high in the next years to come.

##### **(2) Adjusted movement of vehicles (lower speeds, continuous movement)**

Driver education to save energy has become popular and it is reported that this measure alone can lead to reductions of about 5%. It is achieved through smooth and precautious driving, minimizing the acceleration and deceleration cycles and lowering speeds. Considering the latter one has to add that usually trucks go higher speeds than allowed because overrunning speed limits is not penalized in most countries if the overrun is less than 10% of the limit. Furthermore, bypassing of slower vehicles is reduced in energy efficient driving as small speed differentials bring little time advantage.

##### **(3) Better loading of vehicles**

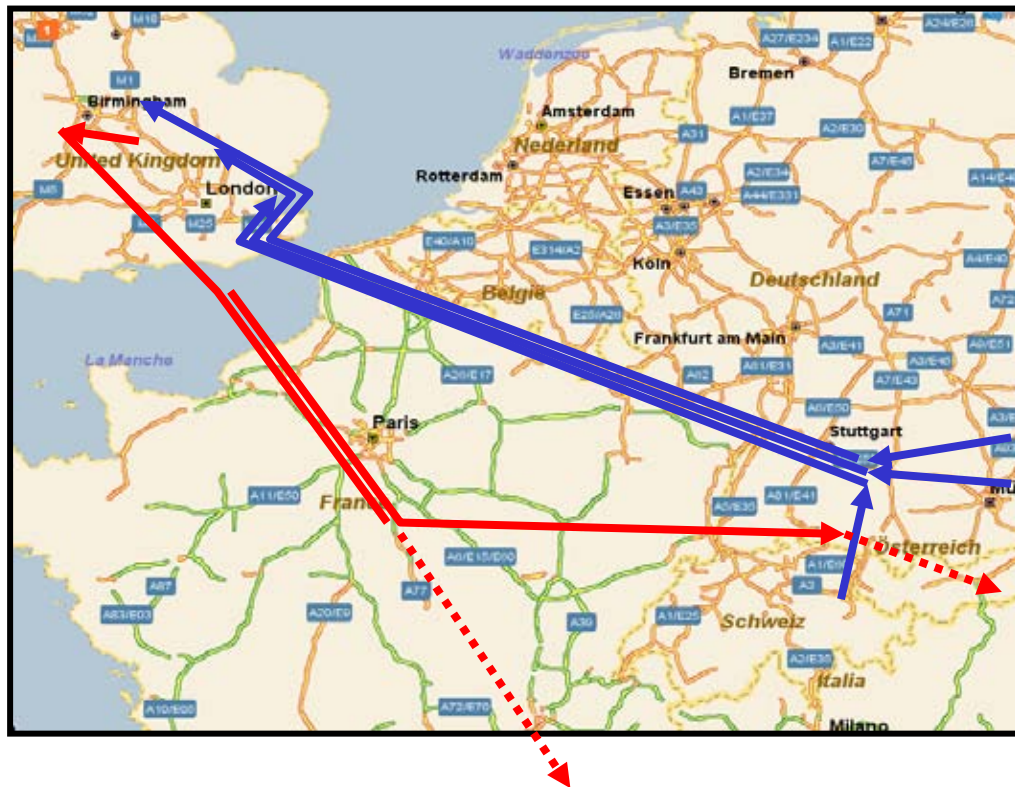
Better loading of vehicles means in many cases that the fixed time tables of departure are substituted by flexible departure times. For instance formerly services like “Frankfurt-Paris, daily, departure x o’clock” were offered, which have been replaced by flexible tours with full loads.

##### **(4) Improved planning of tours and organizing return loads**

One way to increase efficiency and energy use is to reduce empty running of trucks. In many cases tours can not be paired in a way that tour and return tour are symmetrical. This is shown by the example in Figure 2: The company collects the load from south-west parts of Germany



with destinations in London, Hull and Manchester. For the return tour load is collected partly in Liverpool and south-west to London and carried to Paris. Parts of the load are unloaded in Paris and added to the truck load of a French haulage company which serves southern France. The rest is carried to Stuttgart where parts are loaded on a truck of a third company serving southern Germany. The example underlines that the intelligence of the business lies in the first instance in planning the tour in a way that the moving capacity is optimally loaded.



**Figure 2: Tour and Return Tour of a Stuttgart Haulage Company**

Source: Liedtke, 2006

#### (5) Less just-in-time and direct delivery operations

Just-in-time delivery has in the past years dominated the logistic requirements of the shippers. The hauliers have adjusted to these performance requirements successfully as long as the major input resources, as there are personnel and energy inputs, were cheap. Low wages through hiring drivers from Bulgaria, Poland or Romania, and low fuel prices were – together with improved logistics – the reasons for a drastic decrease of road freight transport cost in an order of magnitude of about 40% after starting the EU liberalization on this market. In the present phase of the economy wages are going up and in particular the energy prices are biting. Together with user tolls on highways and motorways, which have for instance been introduced in Switzerland, Austria and Germany and increased in Italy, Spain or France this has lead to a substantial increase of variable costs of trucking. As just-in-time service and direct delivery are in many cases causing an inefficient use of loading capacity one can observe that just-in-time is successively substituted by just-in-sequence delivery. This means that the

schedule of industrial workflow is determining the frequency of delivery, and often this can be adjusted in a way that wider time windows are opened for the transport service.

(6) Integration of rail, inland waterways or coastal shipping in long-haul supply chains

While just-in-time requirements in general could only be fulfilled by road transport the just-in-sequence principle also allows for integrating rail, inland waterways or coastal shipping. The crucial performance requirement is not so much the total delivery time rather than the reliability and punctuality of the service. This is in the case of railway service highly influenced by the number of transshipment operations on the tour and the number of changes of borderlines. The railways still have big difficulties with fulfilling this essential performance requirement, but first examples show that there is a big potential. In the New Opera project of the EU it is estimated that the railways could triple their transport volume (in tonkm) until the year 2025 if they could exploit the inherent potentials in their organization.

(7) Better pairing of transport alongside busy corridors

On the trans-european corridors there is presently a dominance of North-South transport because the ARA ports (North Sea) are very strong, attracting most freight volume and transshipping the freight to the south, south-west and south-east. Analyzing the gravity power of ports one comes to the conclusion that the Mediterranean ports have much more potential than they are using presently. The reasons are in most cases missing efficiency and missing links to the land-borne networks. In the future this picture might change and one can observe that the major players in the logistic business increase their activities in the Mediterranean ports. As a result the long-haul transport alongside the North-South corridor could be better balanced and the transport capacity better used. This concerns the railways in the first instance, which presently show a poor loading on international return tours.

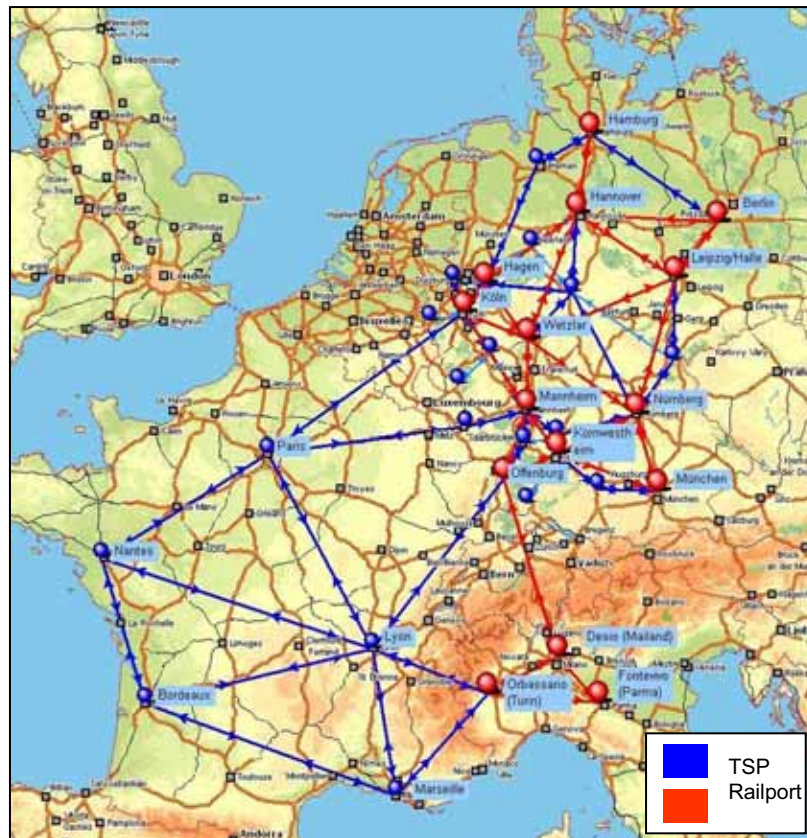
(8) Better consolidation at bundling points through establishing alliances of shippers

The example in Figure 2 demonstrated how firms can increase the transport efficiency through co-ordinated logistics. Such co-operations have only developed in the small but not in the large, i.e., bringing the logistics of big players together. Main reason is that the big companies are afraid of losing privacy of their individual strategies. Logistics is seen as a part of the firm's strategic potential and therefore there is little propensity to form alliances in this market. Question is whether the increasing pressure on variable costs will create incentives to start co-operative solutions. It is a basic proposition of this paper that most of the logistic potential for reducing energy consumption and CO<sub>2</sub> emissions lies on the field of bundling activities of the market players.

### **Development of Marshalling Yards to Railports**

Marshalling yards are traditionally used as points to block and make up freight trains. The new idea is to use these points as centers for freight processing and eventually additional value adding services. This presupposes that the volume of freight is high enough, i.e. pallets of unitized goods have to be consolidated to generate wagon loads, wagons are composed to wagon groups with identical destinations and wagon groups are blocked to form full trains. If such a process can be organized in a competitive way then this could be the point of departure towards a revival of single wagon operations in a rail system. From the perspective of railway companies this would lead to a new and innovative field of activity with strong support of communication systems (tracking and tracing of wagons and eventually pallets), automatic

processing at railports and automatic blocking of trains (automatic coupling technology). Figure 3 gives an example for the allocation of railports and transshipment points from the view-point of the Deutsche Bahn AG.



**Figure 3: Example for a Network with Railports and Transshipment Points (TSP)**

Source: LOGOTAKT, 2008

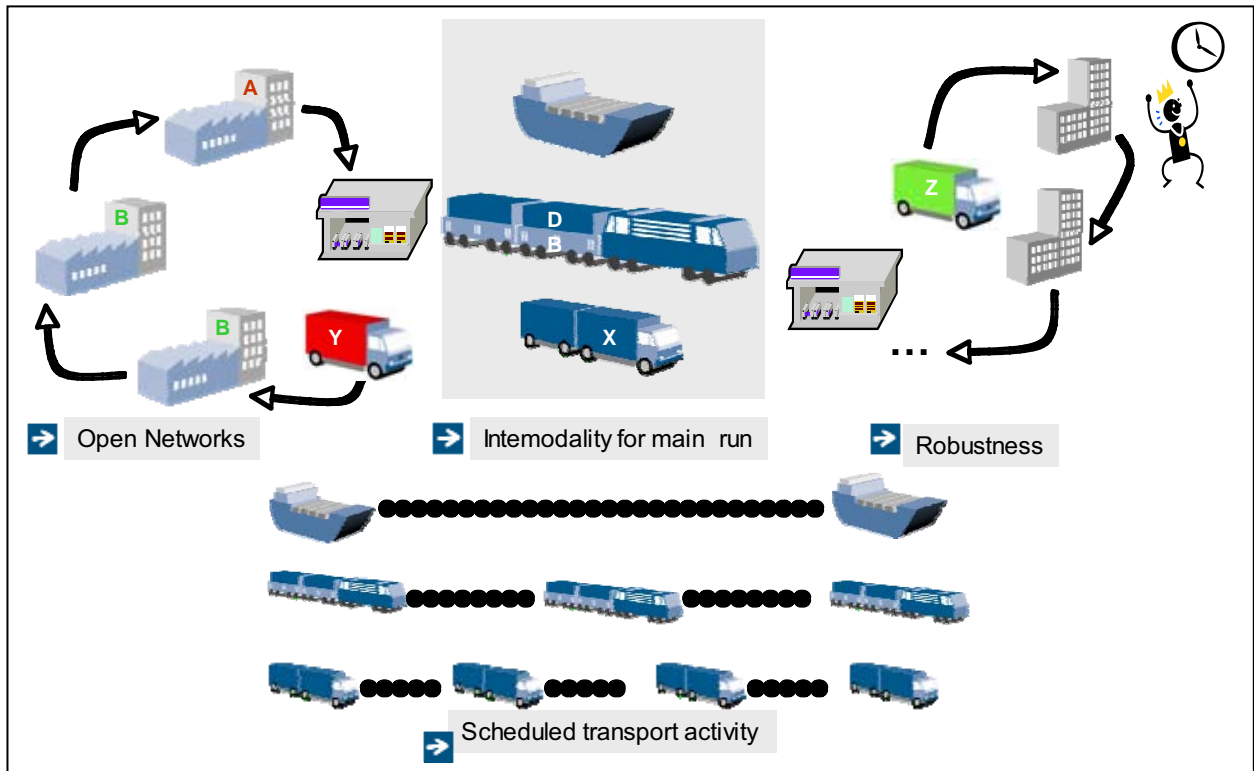
## 4 The LOGOTAKT Concept

### The General Concept

LOGOTAKT stands for a strictly scheduled logistic service, trying to consolidate the freight consignments at bundling points and using the appropriate means of transport for every segment of the transport chain. Contrasting the usual logistic schemes which try to optimize the system and the processes for a single firm LOGOTAKT tries to bring together the transport needs of many players to consolidate their consignments. This means that in a logistic environment which is characterized by a trend of diminishing size of individual consignments LOGOTAKT can be thought as a virtual moving logistic platform with fixed entry and delivery times which serves many players and aims at substantially increasing the volumes of transport on the major corridors.

This can be achieved through an open network to which every firm has access, in principle. Therefore it is not sufficient to develop the logistic concept, only. Furthermore, a business model has to be created to set the conditions clear under which the firms can participate, determine a pricing/cost allocation system for the transport services and establish a concept

which guarantees privacy for the participating players such that no party has to sacrifice internal business information. Figure 3 shows the important elements of the concept.



**Figure 3: Basic Elements of LOGOTAKT**

Source: Logotakt, 2008

There are a number of pre-conditions for the acceptance and the success of the concept:

- Use of modern sensor and communication technology.
- Application of automatic processing for consolidation, loading/unloading and train blocking.
- Crossdocking for time sensitive freight from light to heavy goods vehicles or rail wagons.
- Reliability and robustness of the processes, optimization of buffering.
- Savings of inventory holding.

At the end of the day the participation in the virtual moving platform has to be profitable for the firms. This does not mean that the transport processes as such have to be cheaper or faster compared with the stand-alone optimization of firms. It is the total costs of the logistic systems and the logistic processes which have to be compared to each other. There is some probability that LOGOTAKT will be a profitable system if firms are facing the following situation with and without:

Without (stand-alone)	With (participation in the network)
High volumes per transport activity (e.g. trucking tour)	Smaller volumes per transport activity
High speed of vehicles to guarantee just-in-time delivery	Lower speeds feasible, if schedules not disturbed
Big time intervals between transport activities	Smaller time intervals between transport activities, e.g. 6 hrs. service
Relatively high minimum inventory holding for preliminary goods	Reduction of inventory holding for preliminary goods
Relatively high minimum stock of produced articles	Lower minimum stock of produced articles
Relatively high variance of volumes, therefore special direct tour necessary	Smaller variance of volumes, higher reliability, less special tours
High buffering and physical swaps	Controlled and low buffering, no physical swaps

**Table 1: Conditions for Profitability of LOGOTAKT**

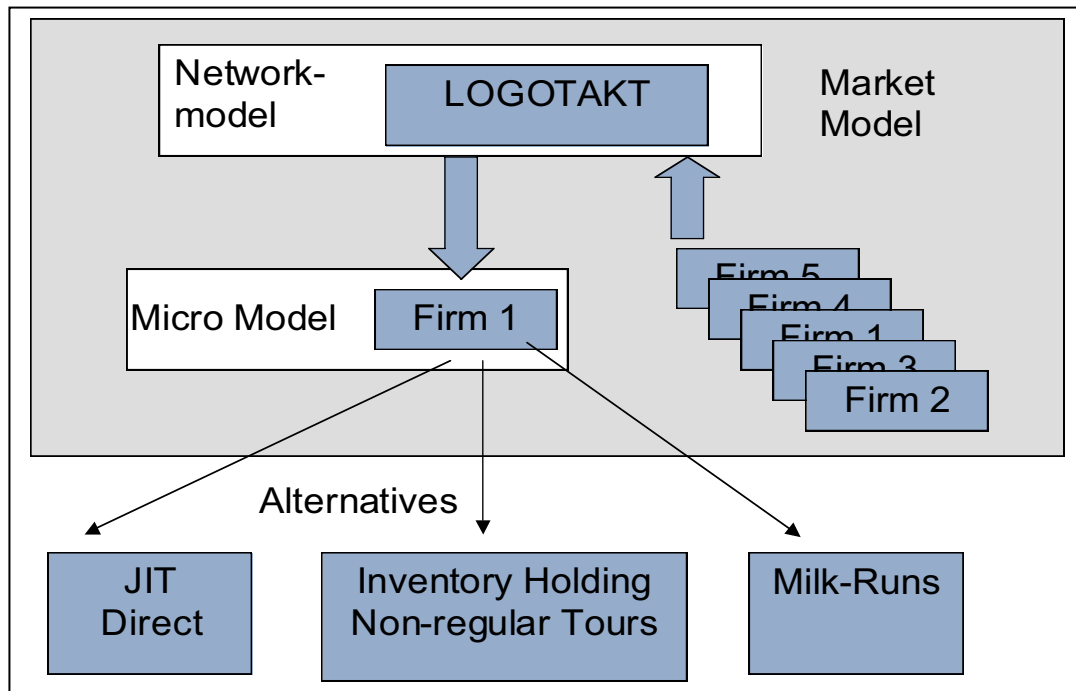
### **Some Scientific Challenges**

LOGOTAKT is generating a number of new scientific challenges for different disciplines of economics, engineering and computer science. Although focus is laid on the economics part one can immediately see from Figure 4 that the economic approaches are closely related to the contributions of the other disciplines or intrinsically interdisciplinary (such as micro and macro-modelling). The following aspects deserve particular attention:

#### **(1) Micro-modelling of logistic and transport activities**

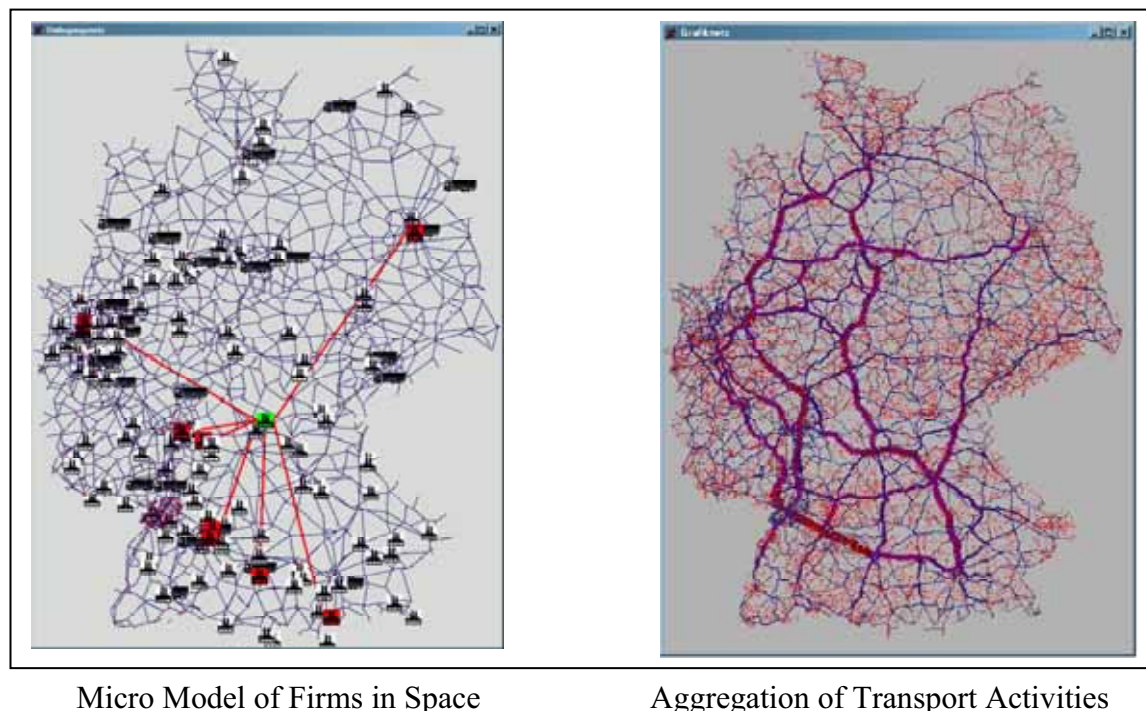
Micro-modelling means in this context that the behavior of single shippers, forwarders, transport companies and recipients (producers, consumers, retail businesses) is simulated individually. While there are a large number of logistic optimization models existing trying to find out optimal solutions for specified logistic problems of a single firm by using optimization techniques and graph theory there exist only a few approaches which can be aggregated on a system's level. Liedtke (2006) has presented a prototype model, which starts with randomly distributing firms in space, assign production activities to these units and generate transport needs. Transport orders are traded on a simulated market and assigned to forwarders which hire transport firms for performing the tours. Consignments are allocated to vehicles and the ours are allocated to the infrastructure networks. In this step it is important to disaggregate the transport needs in enough detail to simulate the typical transport patterns related to commodity groups. This simulation process, carried out with the software INTERLOG, allows for aggregating individual transport activities using distributions and constraints derived by aggregate statistics. As a result the aggregate statistics are reproduced by a pattern of individual activities. In principle there are an infinite number of individual activity patterns which can generate the aggregate picture. Comparable to the theory of traffic distribution in space one can identify a pattern of individual activities which has the highest probability to occur.





**Figure 4: LOGOTAKT Modelling and Checks for Improvement**

Source: Logotakt, 2008



**Figure 5: Micro Modelling of Firm's Transport Activity in Space and Aggregation**

Source: Liedtke, 2006

Until now such a micro-macro-modelling is only possible for about 60% of the freight transport activities in Germany. Analyzing the remaining market segments one can assume that they are less affine to the LOGOTAKT service (e.g.: bulk cargo, (frozen) food, fruit). Figure 5 shows that the aggregated micro flows reproduce the traffic loads by trucks on the

German motorway and highway system fairly well. To make the picture complete, a macro simulation for freight and passenger flows is applied and co-ordinated with the aggregated micro flows. The complete macro flow pattern is used to derive the resistance parameters for the network links (time and operating costs) which are inputs for the micro-simulation. This feedback modelling mechanism is applied for time intervals of the day to take the different traffic conditions into account. The foundation for this micro/macro-modelling procedure has been laid through the OVID project for the German Ministry of Research and Education (Ovid, 2003).

### Preliminary Results for Selected Companies

Before the main phase of the study was started a rough estimation of the LOGOTALT potential was carried out for two selected companies, for which the data base for all operations for a selected time periods were made available. Four scenarios were run:

- Scenario 0: Transport by trucks, only (Base Case)
- Scenario 1: Transport by rail on the main carriage
- Scenario 2: Transport by rail on the main carriage, access/egress organized by individual firms)
- Scenario 3: Least cost organization of transport using the LOGOTAKT concept (open access).
- Scenario 4: Least cost organization of transport using the LOGOTAKT concept (closed shop).

#### (1) Potential for a large company

	Cost comparison (%)			Vehicle km		
	Transport cost %	Transshipment Cost %	Total Cost %	Total km road	Delta km Road %	Total km rail
<b>Scenario 0</b>	95.3	4.7	100	2,471,291		
<b>Scenario 1</b>	93.9	7.3	101.2	411,593	-83.3	2,439,645
<b>Scenario 2</b>	92.2	5.0	97.2	458,935	-81.4	2,439,645
<b>Scenario 3</b>	86.3	5.1	91.4	1,496,892	-39.4	1,194,973

**Table 1: Effects of Different Scenarios on Traffic Activity and on Costs**

#### (2) Potential for a medium sized company

	Cost comparison (%)			Vehicle km		
	Transport cost %	Transshipment Cost %	Total Cost %	Total km road	Delta km Road %	Total km rail
<b>Scenario 0</b>	100		100	6,334,000		
<b>Scenario 3</b>	65.7	4.8	70.6	2,305,000	-63.6	2,425,000
<b>Scenario 4</b>	91.6	5.0	96.6	6,579,000	+3.9	645,000

**Table 2: Reduction Potential for Vehicle kms and Transport Costs (2 Selected Companies)**

Source: LOGOTAKT

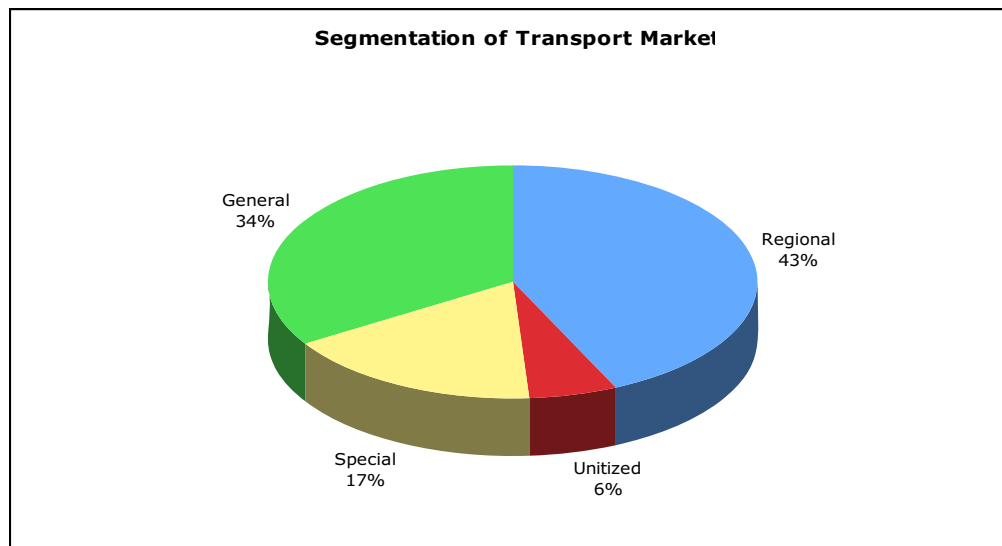
The time base has been chosen differently for the companies such that only the relative figures matter. With respect to these relative figures it is necessary to underline that this exercise was to quantify the potential and not the expected value of realization, considering all barriers to introduce the concept properly. With these restrictions for the interpretation of the figures in mind one can derive the following results:

- (1) The potential of cost savings and of integrating the railways in the long-haul transport chain seems unexpectedly high. Of course this presupposes that the railway companies become commercially efficient and reliable partners, which until now is underlined by many studies (see for instance the New Opera study for the EU Commission, which forecasts a tripling of rail freight transport until the year 2025 and derives this figure from a substantial improvement of technical and organizational capability of the railways.) However, only a few railway companies are actually on the way to achieve the necessary logistic performance.
- (2) Just-in-time and direct service can easily be shown inferior to a scheduled moving platform, because the latter needs less inventory holding, additional tours with suboptimal loads and physical swaps.
- (3) Introducing LOGOTAKT as a closed system for a single firm leads to an improvement of logistic efficiency but uses by far not the potential which is offered by an open system with a set of players. Single optimization with LOGOTAKT might lead to more traffic although the total costs are decreasing. This underlines that an incomplete realization of the concept can lead to counterproductive results with respect to congestion and environmental impacts.
- (4) It is very important to identify the critical mass for the financial viability of the service. Below the critical mass considerable losses might occur because of idle capacity. Above the critical mass there are "Mohring Effects" possible in the way that the incremental costs of access for additional firms are strictly decreasing.

### **Approach to Estimate the Critical Mass for LOGOTAKT**

LOGOTAKT affine segments can be found in the market for general cargo transport. This includes for instance consumption and investment goods, preliminary goods, food, building materials or liquid chemicals. Other markets are less relevant. Regional transport is organized differently, in many cases on a day-to-day basis, Special and unitized transport tasks require special vehicles or swap bodies, have to be organized on an individual time schedule and thus can hardly be integrated in a general logistic platform.





**Figure 6: Segmentation of the German Freight Transport Market**

Source: LOGOTAKT, 2008

For the LOGOTAKT affine market segments a multi-agent model has been established to check for the thresholds which are relevant for the profitability of the concept for the companies.

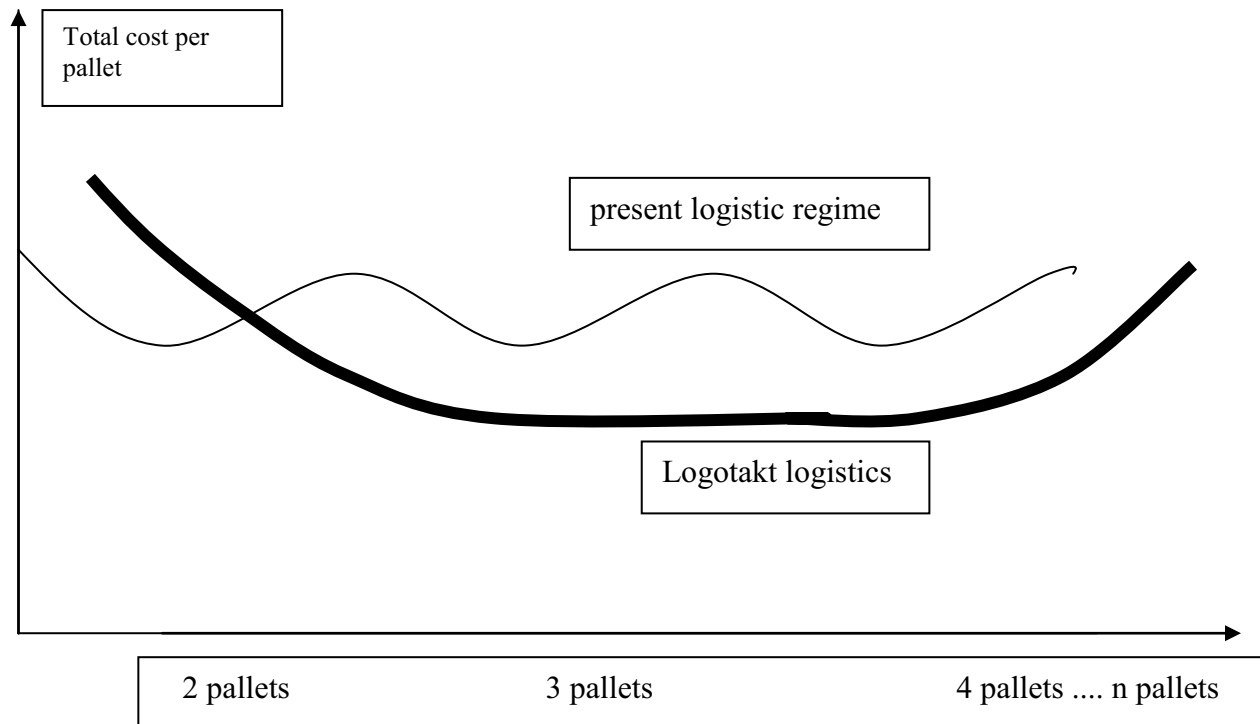
Without referring to the details of the model and the data output derived from first applications one can draw some general conclusions:

- (1) There exists lower and upper bounds for profitability with respect to the volume of freight, measured by the number of pallet loads.
- (2) The relevant range is determined by
  - value of the consignments
  - fluctuation of production
  - probability of extra tours (in addition to the planned tours)
  - cost of inventory holding.

Depending on the combination of influencing factors the lower bound is in the order of magnitude of 2-3 pallet while the upper bound widely differs. In exceptional cases it is about 4 pallets (low value, low fluctuation, little probability of extra tours, low cost of inventory holding) in other cases more than 40 pallets. Figure 7 gives a sketch of the principle shape of the cost functions for stand-alone and LOGOTAKT logistic regimes. While the existence of a lower bound is easily explained through the fact that a minimum volume of transport is necessary to justify highly frequent shipments of goods at low costs the existence of upper bounds is not intuitively understandable. But as a matter of fact each company has the alternative to ship their goods with own or contracted vehicle capacity and can derive increasing returns from higher volumes of shipment. As soon as the integration of the railways into the supply chain is possible at reasonable costs the upper bound goes up substantially and even may vanish. But note that the first comparisons have been carried out under restrictive assumption such that it is not possible to give more exact numerical estimators.

The estimation of the total transport volumes of companies which are LOGOTAKT affine gives a high certainty that there is a market for the system. The minimum turnover which is

necessary to run the system with a low frequency (one service per 12 hrs) is overrun 15 times in the simulation which justifies the expectation that a considerable subset of entry and transshipment points can be served even on a 4 hour basis. This would increase the potential and attract freight transport with higher logistic requirements.

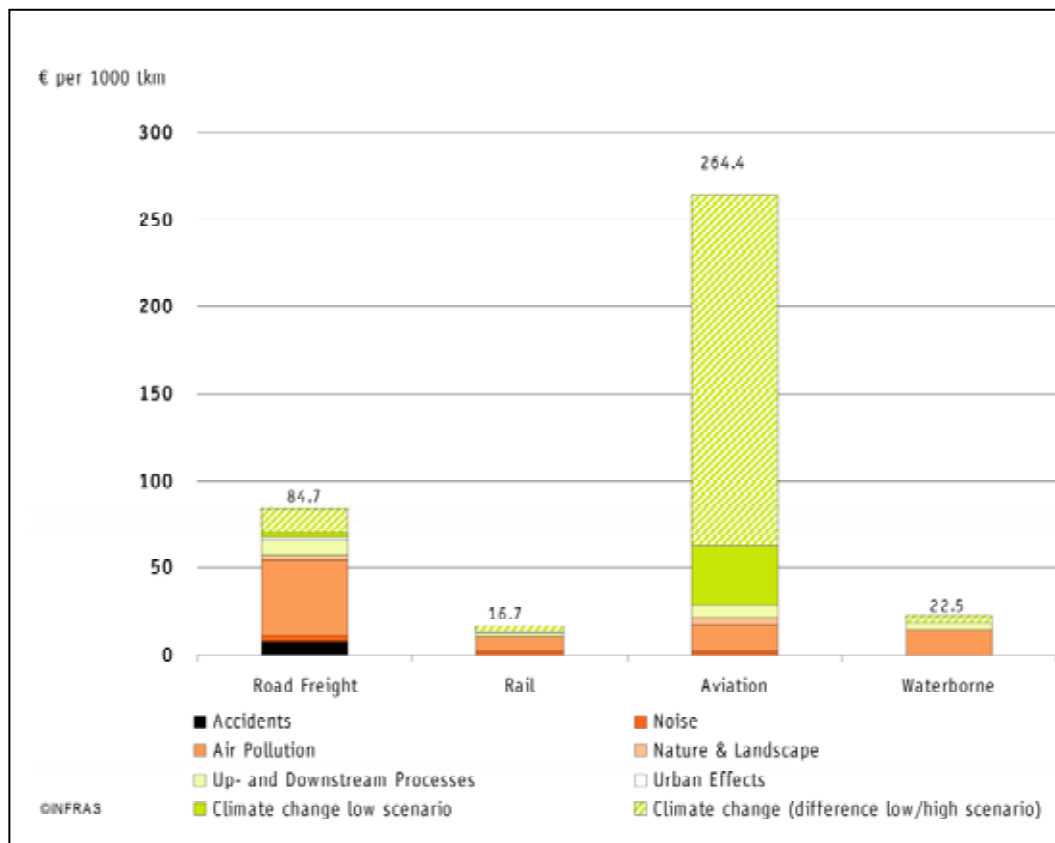


**Figure 7: Example for an interval of profitability (sketch of principle results for consignment values of about 50,000 Euro/ton)**

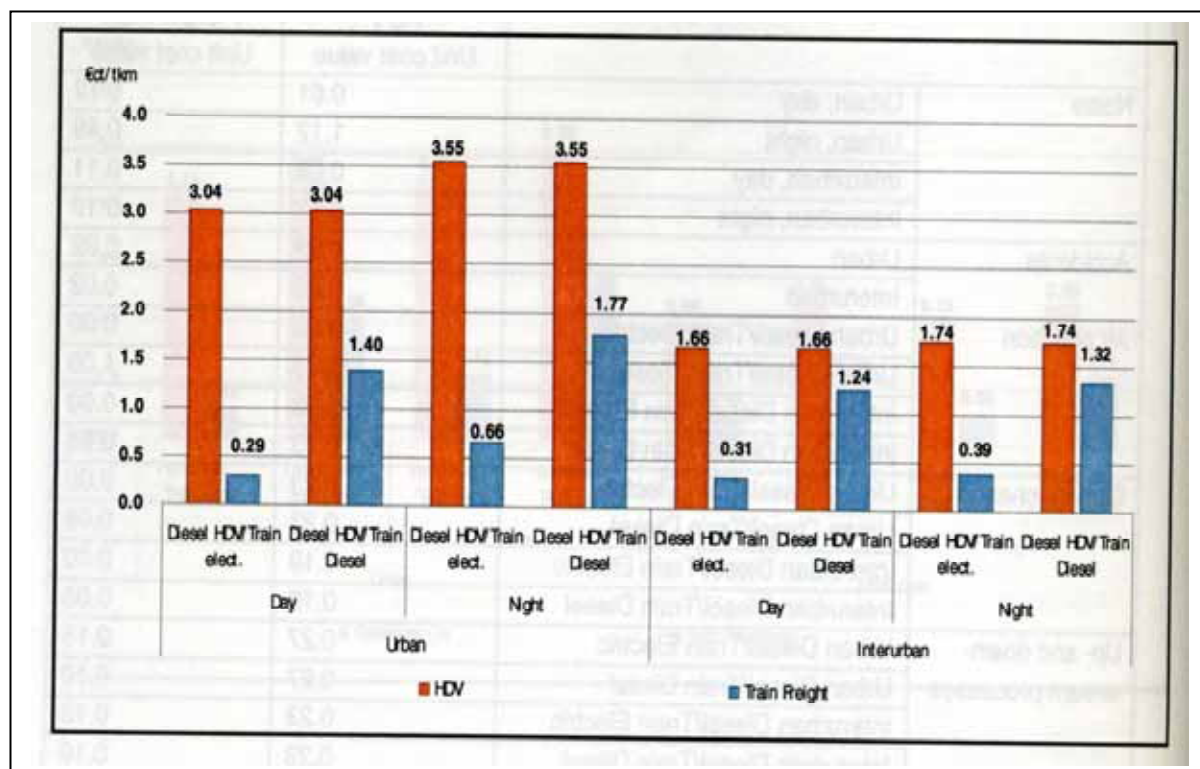
Source: Pischem, 2008

## 5 Effects on road transport and CO<sub>2</sub> emissions

For the firms analyzed the savings of external costs can be calculated on the base of the Handbook (CE et al, 2008) for marginal costs or of the study FACORA of Infrac/IWW (2004) for average costs. As it is more easy to compare and aggregate average figures we take the latter cost basis. The average values for different modes of freight transport are exhibited in Figure 8.



**Figure 8: External Cost of Freight Transport**  
Source: Infrast/IWW, 2004



**Figure 9: External Cost Comparison in the EU Handbook**  
Source: CE et al., 2008

The recently published Handbook is based on the marginal cost philosophy which has dominated the EU financed studies internalisation of externalities since 1998, when the White Paper on Fair and Efficient Pricing was published by the Commission. Although there are a number of literature pieces which criticize the strong and abstract assumptions of neo-classical welfare theory it still can be regarded the main stream of economic approaches worked out for the Commission (see Rothengatter, 2003). The consequence of this approach is that the weight of external congestion costs (time and operating costs exceeding the optimum) is relatively high while the weights of external costs of accidents, air pollution and climate change is relatively low. In the comparison table of Infrast/IWW congestion costs is not considered because it represents a different type of externality. Congestion costs are external to the single users because they don't perceive their contribution to the increase of time and operating costs. But they are widely internal to the set of all users such that they do not affect the competitive balance between transport modes negatively for the competitors. Keeping this in mind an intermodal comparison between different modes of transport including congestion costs is not meaningful. Therefore we restrict to the Infrast/IWW picture. Infrast/IWW have used two different values for the ton of CO<sub>2</sub>, 20 Euro (low) and 140 Euro (high). Evaluating the recent IPCC reviews and the Stern review, followed by a series of high level political activities to reduce CO<sub>2</sub> emission world-wide, only the high value fits into this scenario of high political concern.

Starting from these preliminaries we can give a rough estimation of the effect of introducing the LOGOTAKT system. Taking the figures from Figure 8, adjusting them to the tonkm scale and weighing them with the values of Table 2 we result in a reduction of 33% for firm 1 and 56% for firm 2. As the estimation for the potential of firm 2 seems to be very optimistic we take only the first reduction figure and apply it to the LOGOTAKT-affine market share of 34 %. Result is a savings of external costs and of CO<sub>2</sub> in an order of magnitude of 11%. Taking into account a reduction potential from technology (engines, aerodynamics, tyres) of 5% and from driver education of 5% we result in a total reduction potential of 20% in the next years.

It is highly probably that also in the non-affine market segments, this is two thirds of the total, there is a some potential to save external costs and CO<sub>2</sub> through better logistics. But other concepts will be needed to quantify this potential. One example is the market for parcel service which is fastly growing. In the past this was a market for air cargo and trucking, using different sizes of vehicles. It is hard to discover a potential for energy reduction, looking at the logistic operations from an outside view. However, as soon as the incentives are set right, the management of firms might discover unexpectly high potentials. One example is the DHL company, which has set the target to reduce energy consumption and CO<sub>2</sub> emissions by 30% until the year 2020, based on 2007. The main instruments are the integration of railway service on a main corridor (Frankfurt-Leipzig, served by a high-speed parcel train by night), optimal stucture of the truck fleet, education of drivers and optimal planning of milk run tours.

A second example is the Webasto company which is producing roofs for Volkswagen cabriolets in Portugal. In a first round of optimisation they optimised milk runs for the German supply industry, consolidation of tours and routing from Germany to Portugal, which saved about 25% of transport costs, and energy consumption in a similar range. In a second round they are looking for partners among the other Volkswagen suppliers in Portugal. This would be a frist step towards a closed LOGOTAKT system. In a third step, under the assumption that there is enough transport volume, the railways could be integrated, constructing a supply corridor from Germany to Spain (2 Volkswagen plants) and Portugal (1 Volkswagen plant) together with other companies in an open network. This underlines that

also in segments which presently don't appear to be affine for regular high frequency logistic service with open access the decision situations can change in the future.

## **6 Potential to Reduce CO<sub>2</sub> Emissions of Freight Transport Through Efficient Logistics**

It is a big challenge to make freight transport so energy efficient that the global EU reduction targets can be met. Although this market seems to be growing with high rates in the medium future a high reduction potential can be identified. Looking at the two companies which have been analysed in some detail with respect to their present logistic patterns and the reduction potential through implementing the LOGOTAKT concept one results in figures between 33 and 56% for the LOGOTAKT-affine market segments. Assuming that the 56% reduction simulated for the medium sized firm are too optimistic and the 33% simulated for the large firm are more realistic, and weighing this figure with the market share of LOGOTAKT-affine transport one results in an average figure of 11% for the CO<sub>2</sub> reduction potential. This is achieved by a high frequently turning logistic platform and an open network to foster co-operation of the players. If we add 5% for technological improvement until 2020, which is according to trend development and a further 5% which can be achieved through driver education and assistant systems to smoothen driving cycles one results in an average figure of more than 20% which the sector freight and logistic can contribute to CO<sub>2</sub> reduction in industrialised countries. Last but not least there is some probability that also in the market segments, which are not LOGOTAKT-affine (66% of the total) there is at least a small potential which can be added to the above figure.

One can argue that this estimation is theoretical and derived from simulation exercises. But there are already best practice examples from the industry which point to the same order of magnitude, i.e. 20-30% (see the cases of the companies Webasto and DHL). A central condition has to be met, however: Energy prices have to go up further, not so dramatic as in the past three years, but observable for the market players. This will stimulate a lot of decentral incentives in the companies to save energy and increase the acceptability to form logistic alliances or to participate in an open logistic network.

As a result there is no reason to exclude the logistics sector from the global EU CO<sub>2</sub> emission reduction targets. Despite the expected growth of freight transport in the future there is a high potential to achieve substantial energy and CO<sub>2</sub> reductions by intelligent logistics.

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# A METHODOLOGICAL FRAMEWORK FOR THE EVALUATION AND PRIORITISATION OF MULTINATIONAL TRANSPORT PROJECTS: THE CASE OF EURO-ASIAN TRANSPORT LINKAGES

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**Abstract** - With the globalization of trade and the opening of borders, transport infrastructure projects are becoming more multinational than country specific. Moreover, several countries encounter scarcity of resources to finance them. On the other hand consultants, organizations and authorities are often obliged to perform evaluation of transportation infrastructure projects within a short time span and with limited-data environment. Thus, the need arises for a simplified, flexible and transparent methodological framework to prioritize investments in transport infrastructure located in more than one country. This paper presents such a framework, developed in three simple and consequent phases in order to be used at strategic level by policy makers and cope with limited availability and quality of data. The framework has been applied to prioritize 230 transport infrastructure projects of multinational character, comprising 18 countries from the Euro-Asian region, working together under a UN Project.

**Keywords** - Project evaluation, transportation infrastructure, multinational investment

## INTRODUCTION

Transportation infrastructure is a pre-requisite –though by no means a guarantee- of economic development [1]. This necessitates the improvement of transportation infrastructure and services, especially in less developed countries, which encounter scarcity of resources to finance them. Simultaneously, with globalization and opening of countries' borders, infrastructure projects are characterized more multinational than country specific. This is also verified by the continuous development of initiatives such as Trans-European Networks (TEN-T), Trans European Motorway and Railway networks (TEM, TER), Pan-European Corridors, Euro-Asian Transport Linkages (EATL) etc.

In view of this strategic role of transportation and the limited funding sources (national and/or international), the need arises to evaluate alternative infrastructure investments of multinational character and establish priorities among the different projects.

The tendency today is to deviate from the so far conventional evaluation methods that tend to focus on a relatively limited set of impacts i.e. Cost-Benefit Analysis (CBA) [2]. Decision-makers need to know more than just construction costs and traffic performance; they need information on long-term and indirect impacts on society's mobility as well as the ability to serve diverse needs [3]; and recently they need a better understanding of the social and political consequences of transportation infrastructure projects. Thus, the process of evaluation for selecting a project or a portfolio of projects may reflect social and political issues in addition to technical or more "rational" considerations, which in some cases are not considered critical in the selection process [4].

In addition transportation infrastructure projects can have several goals due to their more international/global character [2]. However, transport infrastructure development can benefit all regions concerned if a proper evaluation method is employed to incorporate all the diverse objectives and interests across the regions. Under this concept, formalistic evaluation methods might not be appropriate.

Moreover, consultants, organizations and authorities are often obliged to perform evaluation of transportation infrastructure projects in short time spans or in a limited-data environment, so comprehensive information might be difficult to be collected and the development of better and sounder simplified evaluation methods is sought. These necessitate the use of Multi-Criteria Analysis (MCA) methods, the criteria of which are formed and refined through observations, discussions, experimentations and mistakes/ corrections.

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Literature review provides a wide range of evaluation methods and/or frameworks for transportation infrastructure projects [5]-[9], listing also various sources of error and bias in them. Consequently evaluation process cannot be a black box; critical judgment is required to probe the importance of every link in a investments prioritization framework. The development of coherent, well structured, flexible and simplified – but not simplistic- evaluation framework with “societal principles”, for transportation infrastructure projects, is quite useful. Few research initiatives exist that adopt an MCA for international transportation infrastructure investment initiatives {[0], some of them combining also a CBA [11]-[13].

This paper presents such a simplified methodological framework, structured in three levels (identification, assessment and prioritization) to secure the inclusion of all proposed projects, by employing sufficient limited criteria reflecting the societal values, the priorities and the available resources of the regions concerned, as well as the viability of the projects and their global/ international character. It is developed in order to be used at strategic level by policy makers and cope with limited availability and quality of data in countries concerned. The framework has been applied to prioritize 230 transport infrastructure projects of multinational character, comprising 18 countries from the Euro-Asian region, working together under a UN Project of ECE and ESCWA.

## METHODOLOGICAL FRAMEWORK

### Overview

The objective of the proposed methodological framework is to identify within a group of projects, the ones for which the investments have to be made in a medium and long-term time horizon, regardless of their geographical location and the region/ country where are physically located. The framework comprises the following phases:

- **PHASE A - IDENTIFICATION:** The identification phase concerns the collection of readily available information/ data regarding projects and identify the prospective projects to be further evaluated based on their funding possibilities and the common-shared objectives of the responsible authorities.
- **PHASE B - EVALUATION:** The evaluation component of the framework is based on a combination of very well-known multi-criteria approaches such as: direct analysis of criteria performance, AHP (Analytical Hierarchical Process) and MAUT (Multi Attribute Utility Theory). MAUT employs sufficient but limited criteria reflecting, among other things, the transport policy priorities of the countries concerned, the available financial resources, the financial and economic viability of the projects and their international dimensions. AHP contributes to overcome subjectivity in deriving criteria priorities using pair-wise comparisons that make difficult to promote open biases towards specific criteria. Direct analysis of criteria performance is employed for deriving criteria scores and can perform relatively well when a limited amount of information is available.
- **PHASE C - PRIORITIZATION:** In the final phase, the prioritization one, the selection of the better performing (in the evaluation) projects takes place and based on these performances, projects are prioritized in four Priority Categories (I, II, III and IV) over a specified time horizon.

### Analysis of Phases

#### Phase A - Project Identification

In this phase the distinction of projects in two major categories, those with committed funding and those without committed funding, takes place. Projects that have already secured necessary funding are not further evaluated and they are directly prioritized as Priority Category I.

Projects without committed funding are further “screened” based on common objectives of the responsible authorities (i.e. national government, local authorities, funding bodies, banks, private sector organizations etc.). The screening levels are three and concern projects’ “relevance”, “readiness” and “viability”. All three levels are simple and easy to apply, so that the projects (local, national and international) that merit evaluation and consequently funding and implementation can be selected from the ones proposed by National Plans.

The “relevance” level, expresses the relevant importance of a project within a group of projects as it concerns the international perspective, and thus the generic criteria used in this level can be grouped under three broad headings:

- (a) Related to international transportation policies and agreements



- (b) Related to national transportation policies and objectives
- (c) Dealing with elimination of cross-border transportation problems (bottlenecks, missing links etc.)

The “readiness” level concerns the maturity of the project in terms of planning and evidence of authorities commitment, and thus the generic criteria used in this level can be grouped under two broad headings:

- (a) Related with project status (existing studies, allocation of work among the responsible stakeholders, time plan for elaboration)
- (b) Related with planning organization’s and implementation authority’s commitment to the project

The “viability” level concerns the expected transportation, economic and social benefits of the project, and thus the generic criteria used in this level can be grouped under three broad headings:

- (a) Related to financial and economic impacts and benefits
- (b) Related to societal and environmental impacts and benefits
- (c) Related to traffic impacts and benefits

Thorough evaluation is performed in the next phase only for projects passing all the three screening levels. Finally, projects without committed funding that didn’t pass all of the screening levels were automatically classified in the last Priority Category (IV), which lists all projects to be implemented at the latest stage of the time horizon.

Last, a secondary objective if this phase is to collect the necessary data in the right format, to serve as input in the evaluation phase.

### **Phase B – Project Evaluation**

The objective of this phase is to derive project’s scores (degree of performance) and compile a record of project’s scores for use in the prioritization phase. The existence of several different types of projects as well as national objectives, favor the use of a method of multicriteria character, than simple monetary methods like CBA. Such a method will allow available information to be taken into account, even at the very preliminary level of project definition. At the same time some specific elements of particular interest for the decision-makers may be introduced. Thus Phase B, includes the following components:

- (a) Definition of criteria
- (b) Measurement of criteria
- (c) Criteria weighting
- (d) Derivation of total score per project

#### (a) Definition of Criteria

The specific evaluation criteria were developed in two “dimensions”:

- the horizontal dimension called “Functionality/ Coherence” expresses the role of the project in the functionality and coherence of the network to be developed.
- the vertical dimension called “Socio-economic Efficiency/ Sustainability” expresses the socio-economic return on investment as well as the strategic/ political concerns of the national political authorities, and of international ones in case of co-financing by them (e.g. EU, EIB, World Bank)

Under these two fundamental orientations of the evaluation process, the following criteria have been introduced, which are aimed at covering all of the objectives and specifics relating to the evaluation of transport projects of international character.

#### **Horizontal Dimension: Functionality/ Coherence Criteria (CA)**

- Serve international connectivity (reaching a border crossing point or provide connection with a link that is border crossing); (C<sub>A1</sub>)
- Promote solutions to the particular transit transport needs of the landlocked developing countries; (C<sub>A2</sub>)
- Connect low income and/or least developed countries to major European and Asian markets; (C<sub>A3</sub>)
- The project crosses natural barriers, removes bottlenecks, raises substandard sections to meet international standards, or fills missing links in the EATL; (C<sub>A4</sub>)

**Vertical Dimension: Socio-economic Efficiency and Sustainability Criteria (CB)**

- Have high degree of urgency due to importance attributed by the national authorities and/or social interest; ( $C_{B1}$ )
- Pass economic viability test; ( $C_{B2}$ )
- Have a high degree of maturity, in order to be carried out quickly (i.e. project stage); ( $C_{B3}$ )
- Financing feasibility ( $C_{B4}$ )
- Environmental and social impacts ( $C_{B5}$ )

**(b) Measurement of Criteria**

Criteria were measured first in a “physical scale” either by direct classification according to available data/measurable characteristics and/or by quality attributes, provided by preference judgment from the involved national authorities.

The physical scale was chosen to be a simple five point with threshold values based mainly on criterion's nature. As an example the physical scale/measurement of criterion of the extent the project is expected to increase traffic (Criterion  $C_{B2}$ ) is presented: A: By more than 15%, B: 10-15%, C: 5- 10%, D: less than 5%, E: Will not affect traffic.

To make the various criterion scores compatible it was necessary to transform them into one common measurement unit or else transform “physical scale” measurement into a common “artificial scale” measurement. Criteria quantification was not be based on a sophisticated utility function but on a simple crooked linear function which connects threshold values of an artificial scale with threshold values of a physical scale. The artificial scale chosen is: A = 5, B = 4, C = 3, D = 2, E = 1, with 5 the highest value. Therefore:

$$C_{ji} \in [1,5] \quad (1)$$

Where:

J = A, B (*representing the criteria dimension*)

i = 1,...,5 (*representing the number of criteria in each dimension*)

**(c) Criteria Weighting**

At this stage, for establishing the criteria weights Saaty's Analytical Hierarchy Process (AHP) was used, because it is simple, transparent and widely accepted procedure. In addition, the existence of Eigen vector method in AHP provides fast and reliable weights: fast in expressing the short time necessary for its application; and reliable in minimising the subjectivity of weights' values. It should be noted here that the resulted criteria weights should add up to unity.

$$W_{ji} \in [0,1] \quad (2)$$

$$\sum W_{ji} = 1 \quad (3)$$

Where:

J = A, B (*representing the criteria dimensions*)

i = 1,...,5 (*representing the number of criteria in each dimension*)

**(d) Derive Total Score per Project**

The total score of each transportation project was calculated by (4), which is based on multi-attribute utility theory, following the work of Keeney and Raiffa [14].

$$T.S._{Project} = \sum_{J=A}^C \sum_{i=1}^5 C_{ji} * W_{ji} \quad (4)$$

Where:

$C_{ji} \in [1,5]$

$W_{ji} \in [0,1]$

$J = A, B$  (representing the criteria dimensions)

$i = 1, \dots, 5$  (representing the number of criteria in each dimension)

### Phase D – Project Prioritization

The objective of this phase is to provide a prioritization of all considered projects, based on their total scores and thus to assist decision-makers to realize the time-order of projects implementation in the desired time horizon. The classification of priority categories is:

- **I**: immediate implementation of projects
- **II**: short term implementation of projects
- **III**: medium term implementation of projects
- **IV**: long term implementation of projects

The total score of each project (resulting from the application of equation 4) puts it in one of the four priority categories. Hence, if:

- the project already has committed funding, it belongs to priority category I.
- the project scores between 4-5 then it belongs to priority category II.
- the project scores 3 -4 then it belongs to priority category III.
- the project scores 1 -3 then it belongs to priority category IV.

## APPLICATION CASE STUDY

### Brief Description of the Case Study

The project of Euro Asian Transport Linkages Development aims at prioritisation of transport infrastructure projects (road, rail, maritime, inland waterway, inland/border crossing) along the adopted Euro-Asian transport routes. More specifically the objectives are:

- to identify and formulate international transport linkages and corridors between Europe and Asia, including highways, railways, inland water routes and seaport connections for multimodal transport operations;
- to identify and promote major international transport facilitation conventions to enhance capacity to improve and harmonize national transport legislation and transport facilitation measures;
- to assist in the establishment and effective functioning of national transport development bodies which are responsible for formulation and implementation of national action plans on transport facilitation and development;
- to establish a database of experts and institutions by each Regional Commission, in consultation with its Member States, other development agencies, and relevant officials of the UN system; to create a website for the project to disseminate information about experts, institutions and project progress; and
- to organize national and regional workshops and expert group meetings for promoting the project's objectives.

The involved 18 countries are: Armenia, Azerbaijan, Belarus, Bulgaria, China, Georgia, Islamic Republic of Iran, Kazakhstan, Kyrgyzstan, Moldova, Romania, Tajikistan, Turkey, Ukraine, Uzbekistan, Afghanistan, Russian Federation, Turkmenistan. The number of infrastructure projects (road, rail, maritime, inland waterway, inland/border crossing) considered is 230.

### Application of Methodological Framework

#### Application of Phase A - Identification

Out of the 230 projects considered 133 projects were directly categorized as Priority Category I, since they had committed funding and from the rest 97, all managed to pass the three screening levels and were considered for further evaluation. For the latter mentioned projects -that passed the three screening levels-, data collection was performed, based on specific project fiches/ templates.

## Application of Phase B - Evaluation

### (a) Definition of Criteria Measurement

#### Horizontal Dimension: Functionality/ Coherence Criteria (CA)

- To what extent does the project improve international connectivity (for example, by reaching a border-crossing point or providing connection with a link that is border crossing; (Criterion  $C_{A1}$ )?  
A: Greatly, B: Significantly, C: Somewhat, D: Slightly, E: Does not improve connectivity.
- To what extent will the project promote solutions to the particular transit transport needs of the landlocked developing countries (Criterion  $C_{A2}$ )?  
A: Greatly, B: Significantly, C: Somewhat, D: Slightly, E: Does not.
- Will the project connect low income and/or least developed countries to major European and Asian markets (Criterion  $C_{A3}$ )?  
A: Greatly, B: Significantly, C: Somewhat, D: Slightly, E: Does not.
- Will the project cross a natural barrier, alleviate bottlenecks, complete a missing link or raise substandard sections to meet international standards along a Euro-Asian Transport route (Criterion  $C_{A4}$ )?  
A: Greatly, B: Significantly, C: Somewhat, D: Slightly, E: Does not.

#### Vertical Dimension: Socio-economic Efficiency and Sustainability Criteria (CB)

- Does the project have a high degree of urgency due to importance attributed by the national authorities and/or social interest (Criterion  $CB1$ )? The project is...  
A: In the national plan and immediately required (for implementation up to 2008). B: In the national plan and very urgent (for implementation up to 2010), C: In the national plan and urgent (for implementation up to 2015), D: In the national plan but may be postponed until after 2015, E: Not in the national plan.
- To what extent is the project expected to increase traffic (Criterion  $CB2$ )?  
A: By more than 15%, B: 10-15%, C: 5- 10%, D: less than 5%, E: Will not affect traffic.
- At what stage is the project (Criterion  $CB3$ )?  
A: Tendering, B: Feasibility study, C: Pre-feasibility study, D: Planning, E: Identification.
- What is the financing feasibility of the project (Criterion  $CB4$ )?  
A: Excellent (IRR > 15%), B: Very Good (IRR between 13% to 15%), C: Good (IRR between 10% to 13%), D: Medium (IRR between 4,5% to 10%), E: Low (IRR less than 4,5%)
- To what extent does the project have potentially negative environmental or social impacts (pollution, safety, etc) (Criterion  $CB5$ )?  
A: No expected impact, B: Slight impact, C: Moderate impact, D: Significant impact, E: Great impact.

Based on the criteria measurement described above, each criterion score was calculated for each project.

### (b) Criteria Weighting

According to priorities set out from the national authorities pair wise comparisons of all criteria were made. The measurement of preference is done according to Saaty's 9-points scale, where 1 implies the base factor is equally equivalent in importance to the other factor, and 9 implies the base factor is overwhelmingly more important than the other factor. For each country different weight are produced, which they are averaged.

The resulting final weights for each criterion are (the subscript denotes first the criterion dimension and then the criterion number in each dimension):

- **Horizontal Dimension: Functionality/ Coherence Criteria ( $C_A$ )**  
 $W_{A1} = 3,13\%$ ,  $W_{A2} = 9,38\%$ ,  $W_{A3} = 19,79\%$ ,  $W_{A4} = 17,71\%$ ,
- **Vertical Dimension: Socio-economic Efficiency and Sustainability Criteria ( $C_B$ )**  
 $W_{B1} = 12,67\%$ ,  $W_{B2} = 12,67\%$ ,  $W_{B3} = 3,33\%$ ,  $W_{B4} = 7,33\%$ ,  $W_{B5} = 14\%$

## Application of Phase C - Prioritisation

The priority categories for Euro-Asian Transport Linkages were:

- **I:** projects, which have funding secured and are ongoing or planned and are expected to be completed in the near future (up to 2010).
- **II:** projects which may be funded and implemented rapidly (up to 2015).

- **III:** projects requiring some additional investigations for final definition before likely financing (up to 2020).
- **IV:** projects requiring further investigations for final definition and scheduling before possible financing

### **Results of the Application**

The application of the methodological framework for prioritization produced the following results for the 230 considered projects.

- 133 projects were classified in the Priority Category I
- 16 projects were classified in the Priority Category II
- 10 projects were classified in the Priority Category III
- 71 projects were classified in the Priority Category IV

### **CONCLUSIONS**

The evaluation and prioritization of transportation infrastructure projects at multinational level requires decisions of public investment that have to be done jointly by the countries where the projects will be implemented as well as international organizations if funding is required by them. Thus, different objectives and priorities, as well as available resources have to be considered, rendering conventional evaluation methods not so useful.

The aim of this paper is to offer decision-makers a methodological framework to prioritise projects in an international context. It is a coherent, well structured, flexible and simple –but not simplistic- with “societal principles”, for the evaluation and prioritization of multinational transportation infrastructure projects.

It is structured in three levels (identification, assessment and prioritization) to secure the inclusion of all projects, as proposed by the countries, to employ sufficient but limited criteria reflecting the societal values, the priorities and the available resources of the countries concerned. On the other hand the viability of the projects and their international character are included as well.

The first basic advantage of the framework is that it “saves time and money” in project evaluation procedure, since the first level rules out projects with insufficient information available and accepts for further evaluation only “mature” projects in terms of funding commitment, data availability and “political” commitment. The same benefit arises from the limited but sufficient number of criteria. In addition, the limited data requirements and the easiness in each application, renders the framework useful for the decision makers in countries with different levels of development.

The application of the framework for the elaboration of Euro-Asian Transport Linkages Development Project has proved its applicability and its ability to produce results that coincide with the national plans and at the same time promote the international transportation connections.

### **ACKNOWLEDGEMENT**

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# CONTAINER PORT THROUGHPUT PERFORMANCE – CASE STUDY: FAR EAST, NORTH WEST EUROPEAN AND MEDITERRANEAN PORTS

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Emir ČIKMIROVIĆ<sup>4</sup> and Ivan KRAPOVIĆ<sup>5</sup>

**Abstract** — This paper tries to examine this issue from two viewpoints, the theoretical and the empirical ones. The first job is to estimate the port capacity performance, and the make empirical studies of major terminal operators in Asia and Europe, to find out their differences. The results shown there are huge differences between major Far East, North West European and Mediterranean terminals and ports. The study is based on data published on the web site of Containerization International (downloaded in the 2005 and 2006) and data from the Yearbook of Containerization International. For each port and terminal data are referred to the waterside operation of berths and QCs are the more important determinants of productivity.

**Keywords** — Port throughput performance, Port productivity measures, Throughput optimization

## 1. INTRODUCTION

We present effect on container terminals capacity performance with numerical results and computational experiments which are reported to evaluate the efficiency of Major Far East, North West European and Mediterranean Ports. The container throughput and terminal capacity performance in the 4 leading port ranges are analyzed in this study (East Asia, South - East Asia, Northern Europe and North - East Asia). Latterly three of the four top port ranges belong to Asia while Le Havre – Hamburg range presents European main port area.

To test the calculation result of ports and terminals, with the assistance of one major container shipping line, the terminal operation data of most ports is collected for the purpose of comparison. The information collected covered the ports and terminals throughput for each port, berth characteristics, terminal performances and so on. Meanwhile, the terminal information in these ports is collected from both the Yearbook of Containerization International and websites, to find both the terminal and berth throughput.

The Far East, North West European and Mediterranean ports and terminals selected for analyze are showing in subsections 2.1, 2.2 and 2.3. The comparison between these ports is made by terminal basis, and Far East terminals and ports are listed in Table 1.

Apart from the classical theoretical references (e.g., [6], [7]), used for develops and describes methodology to study the container port capacity performance in this paper, it was necessary to review some segments of papers (e.g., [5], [8], [9] and [10], in which some individual elements of calculation of the various capacity performances have been considered.

This paper is organized as follows. In Section 2 we give a brief description of the world container port throughput. Also, in this Section we present the Major Far East, North West European and Mediterranean ports selected for capacity performance analysis. Section 3 compares various measures of productivity between Far East (FE) and North West European ports (NEW), as well as Mediterranean ports (including Contship Italia Group – Eurogate (CIG-E)). Comparison of container terminals with leading terminal operators in selected ports is reported in Section 3, also. This implies a visual impact of capacity performance and their influence to ports and terminals productivity. In Section 4, we present effect on container terminal performance with numerical results and computational experiments which are reported to evaluate the productivity of the Hamburg, Hong Kong, Busan port layouts and Contship Italia Group - Eurogate. The final section concludes the paper.

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## 2. WORLD LEADING CONTAINER PORTS THROUGHPUT

The world container port ranking changed significantly between 1996 and 2006, see Figure 1 (Si – Singapore, HK – Hong Kong, Sh – Shanghai, Bu – Busan, Ko – Kaohsiung, Sz – Shenzhen, Ro – Rotterdam, Ha – Hamburg, LA – Los Angeles, LB – Long Beach, An – Antwerp, Du – Dubai, Yo – Yokohama). The total container traffic volume of the 20 top ranking world container ports reached 205.3 million TEU in 2006. These ports increased their handling volume by 10.4 per cent compared with results in 2005, representing approximately 50 per cent of the total world container traffic. New container ports gained momentum (like Tanjung Pelapas) and other ports established their role as international load centers.

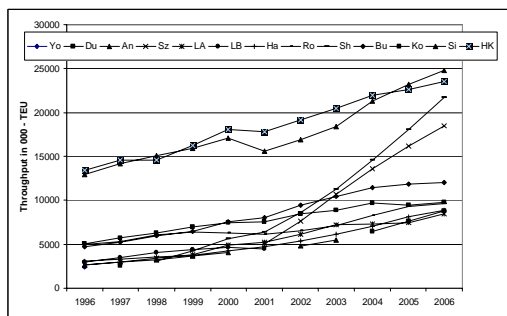


FIGURE 1

The world container port ranking: 1996 – 2006 [2]-[4]

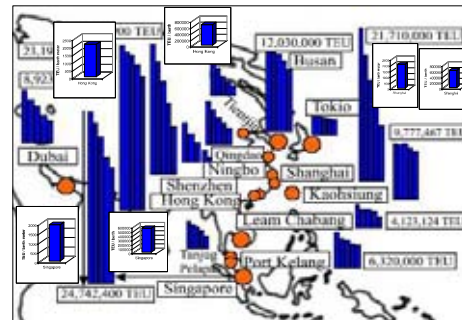


FIGURE 2

Major Asian Container Ports in 2006 [1]-[4]

### 2.1. Far East Ports

Thanks to the development of global economy, especially the rapid expansion of Asian economy including China, the container volume is steadily increasing year after year. Every port makes efforts in its own way in order to make contributions to the national economy by way of creating more value-added. For this study, major Far East container ports have been included in this survey in an effort to secure validity and objectivity. The target ports and container terminals surveyed are as illustrated in the Table 1.

In Figure 2 are presented 16 Far East container ports with container traffic development from 2002 to 2006. All of them belong to 20 Top World Ports in 2006. Some improvements increase production incrementally, by 5-10%, and other improvements make a quantum jump, by 10-20%. This paper deals merely with the increasing of port terminal productivity, as a part of logistic network, due to automation of some ports subsystems like as leading Asian ports.

TABLE 1  
Selected Far East container ports and terminals

Ports	Terminals	Terminal operators	Remarks
Singapore	All together (Tanjong Pagar; Keppel; Brani & Pasir Panjang)	PSA	Web site
Hong Kong	Kwai Chung-Tsing Yi	Different	Web site (Containerisation International)
	1; 2; 5 & 9 South	MTL	
	4; 6; 7 & 9 North	HIT	
	8 East	COSCO-HIT	
Shanghai	3	DP World	Web site (Containerisation International)
	Shanghai Pudong Int'l CT	HPH-COSCO	
	Shanghai CT (SPICT + SCT + Shanghai Midong CT)	HPH-COSCO	
Busan	PECT	Different	Direct survey
	DONGBU	Shinsundae Container Terminal	
	Hutchison Busan CT	Logistics Div. of Dongbu Corporation	
	Gamman	HPH	
	(PECT + Dongbu + HBCT + Gamman)	Different	

Our study reveals that over the past six years from 2000 to 2006, the throughput per berth of each container terminal in Far East ports are steadily increasing year after year, ranging from minimum 300,000 TEU per berth to maximum 700,000 TEU per berth, and showing an average throughput per berth of around 500,000 TEU. This study also shows that during the past six years from 2000 to 2006, the average throughput in TEU per meter of berth length of the container terminals in Far East ports is steadily increase every year



from minimum 1,300 TEU to maximum 2,100 TEU per berth meter, and showing an average throughput in TEU per m of berth length of around 1,700 TEU.

## 2.2. European ports

In an effort to find out the throughput of European container ports, this study has made a survey of the throughput of all the European container ports from 2001 to 2006, updating the existing data of each item by way of first and second data checkup and spot survey. The European ports selected for analysis are: Rotterdam (ECT and APM), Hamburg, Antwerp, Bremen, Gioia Tauro, Algeciras, Felixstowe, Valencia, Le Havre and Barcelona, see Figure 3 [8]. The comparison between these ports is made by total terminal basis, and these ports are presented in Figure 3. Figure 3 presents 11 European Major Ports with development functions of their throughput. The information collected covers the throughput (in TEU) for each port, berth characteristics, terminal performances and so on.



FIGURE 3

Top 11 European container ports with container traffic development: 2001-2006 [8]

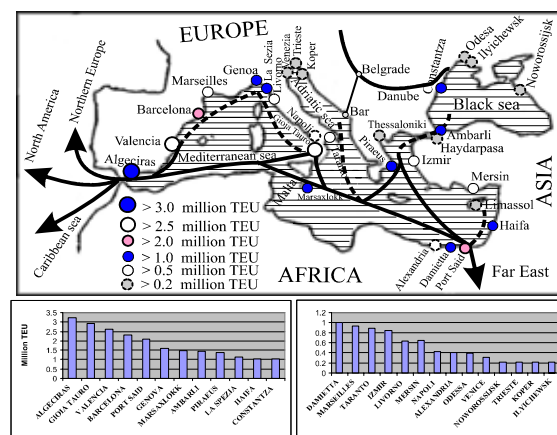


FIGURE 4

Mediterranean container ports in 2006 [2], [3] and [8]

In the two relationship analyses – correlation between throughput performance and terminal land occupied, and correlation between berth throughput and terminal land utilization, we can find out the suggestion related to the optimal throughput calculation. That is, the following 4 factors should be taken into consideration: a) the traits of container traffic (in TEU), b) the traits of berth facilities (the length of berth, number of QC (quay crane) and productivity), c) the traits of container yard - CY (size, number of stack, and storage period) and d) customer service level.

## 2.3. Mediterranean ports

Container throughput growth for South Europe ports including all Mediterranean and Adriatic containerports had felled from 11.9% in 2000 to 6.1% in 2001 and remained close to this level in 2003. Thereafter throughputs increased for about 9.0% in 2004 and the same trend is expected in 2005. In 2001, the Mediterranean region generated 20.9 million TEU, while in 2010 this will have risen to about 40.0 million TEU [3] and [4].

If the Mediterranean ports were not competitive, then it would be reasonable to assume that productivity levels - as measured in terms of facility utilization - would be poor and that there would be little evidence to suggest that they were improving. It is also relevant to contrast the current level and development of terminal productivity. However, Figure 4 summarizes the position of leading Mediterranean ports and their throughput in 2006.

## 3. COMPARISONS OF PRODUCTIVITY BETWEEN SELECTED REGIONS

It is relevant to consider the current level and development of terminal productivity with the situation in broadly comparable regions in the world. That implies the comparison between Far East, European and Mediterranean ports. Considering this, local conditions make direct comparisons with other port markets.

Figure 5 presents the position of major ports in Europe, also the high volume ports in Far East and the overall average noted in selected Asian ports as a whole and partially. Port operation efficiency is examined from the viewpoint of the TEU per berth meter and TEU per hectare that is measured by ports productivity. These performances are shown in Figure 5. The average performances of the port operation efficiency are examined in Figure 5 with parameters for MECP (Major European Container Ports) and MACP (Major Asian Container Ports). On the other hand, Figure 6 shows the relationship between the TEU per berth meter and hectare per berth of major European and Asian ports. These results present the comparison between land utilization and the berth throughput (as illustrated in Figures 5 and 6).

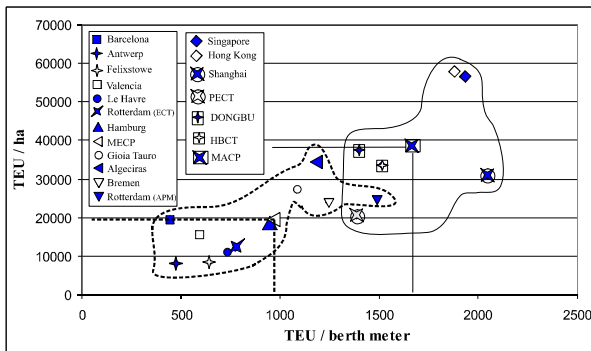


FIGURE 5

The TEU per hectare and TEU per berth meter of Major European and Far East Ports [4]

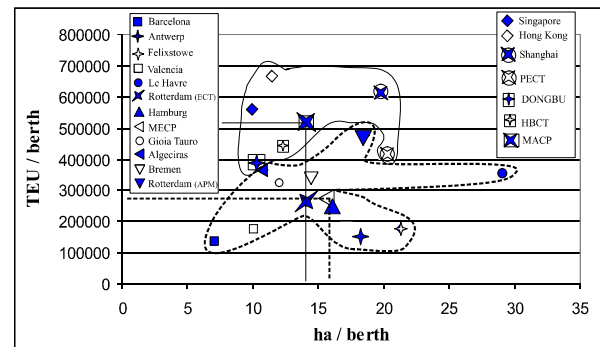


FIGURE 6

The TEU per berth and ha per berth of Major European and Far East Ports [4]

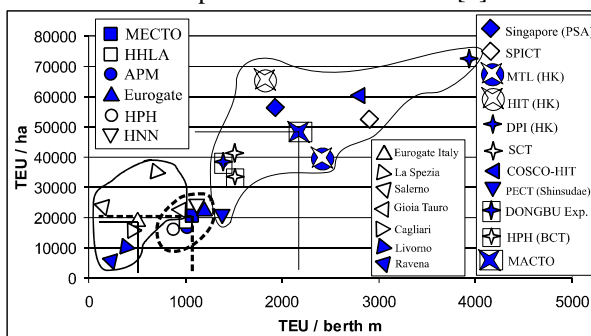


FIGURE 7

The TEU per hectare and TEU per berth meter of the FE, NWE and CIG-E ports/terminals

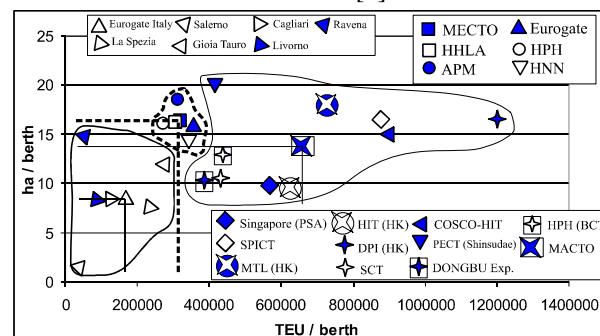


FIGURE 8

The TEU per berth and ha per berth of the FE, NWE and CIG-E ports/terminals

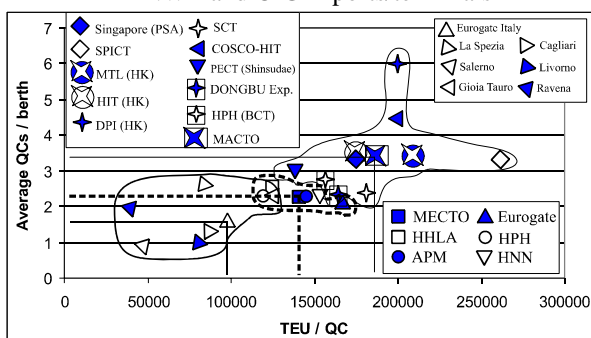


FIGURE 9

The TEU per QC and Average QCs per berth of the FE, NWE and CIG-E ports/terminals

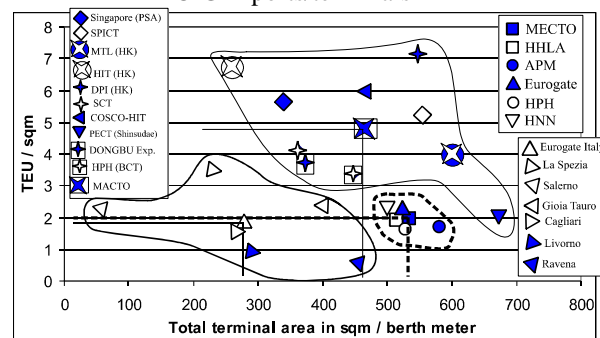


FIGURE 10

The TEU per sq m and Total terminal area in sq m per berth meter of the FE, NWE and CIG-E ports/terminals

**Legend:** In Figures 5 and 6, above mentioned terminals PECT, DONGBU, HBCT make part of Busan port. In Figures 7 – 10 are shown next terminal operators: HHLA-Hamburg Hafen und Lagerhausgesellschaft; EUROGATE-Eurogate Container Terminal Hamburg; APM-Terminals in Rotterdam; HPH-Terminal Operator in Busan; HNN-Hesse-Noord Natie in Antwerp; SPICT, SCT,-Shanghai; COSCO-HIT-Hong Kong; DONGBU, HPH-Busan.

Figures 7 – 10 shows a summary of the terminal operation parameters of major terminals in Rotterdam, Hamburg, Antwerp, Singapore, Hong Kong, Shanghai, Busan, including Contship Italia Group - Eurogate. Container Terminal Operators own terminals with operation efficiency that is examined from the viewpoint of the TEU per berth meter, TEU per hectare or square meter, TEU per QC and TEU per berth that are measured

by ports productivity. The average performances of all their terminals are also present in Figure 7 – 10. The results suggest the differences between the TEU per berth, TEU per berth meter, TEU per hectare or square meter, TEU per QC and average QCs per berth. In addition, these Figures present average value expression for all terminals and whole ports. The position for quay and land utilization is further detailed in Figures 7 and 9. In all these Figures 7 – 10, MECTO and MACTO present the average values for the specified terminals and ports. All of them are measured under berth basis, with 300 meters of quay length.

In the past few years we have seen a process of concentration in ownership of container shipping lines and have also observed the development of relatively long-lasting consortia between some of the major shipping lines. When these trends are considered in connection with the steady increase in ship sizes that has been recorded, it is apparent that the size of stevedoring contracts has increased sharply.

The market is also forecast to expand at growth rates of between 5.4 - 10 per cent per annum up to 2010 and then between 4 - 6 per cent in the following period. Within this total, the deep-sea and transshipment sectors will expand at a considerably more rapid pace. This means that not only will significant initial capacity have to be provided but, also, a port must be able to offer capacity to meet rapidly expanding requirements for large customers.

The service level provided by a port is a function of numerous factors - ship lines in port, container dwell time, handling systems and port efficiency, etc. It is far from clear that the insistence of multiple terminals in a port would have any positive effects on these issues. Clearly, a fragmented container port would more likely, result in additional port stay costs, higher intra-terminal transit traffic, costs from consolidating full barge and rail loads, etc. This would have the effect of decreasing the competitive position of the port.

#### 4. COMPARISONS OF PRODUCTIVITY BETWEEN SELECTED PORTS

For selected Container Terminals from Port of Hamburg, Port of Busan, Port of Hong Kong and Contship Italia Group, operation efficiency is examined from the viewpoint of the TEU per QC, TEU per berth, TEU per hectare and TEU per berth meter that are measured by ports productivity. The performances of these Container Terminals are shown in Figures 11 – 14. The results reveal significant differences between the TEU per berth meter, TEU per hectare and TEU per berth. The position for quay and land utilization is further detailed in Figures 12 – 14. The average performances of these terminals and ports are also presented in Figures 11 – 14.

The Port of Hamburg achieved a throughput of 6.1 million TEU in 2003, 7.003 in 2004, 8.088 in 2005 and 8.862 in 2006, an increase of 14.2%, 13.0%, 13.5% and 8.8% over the previous year, respectively. In the same time the Port of Busan reached 12.075 million TEU or an average increase of 6.22% per year while the Port of Hong Kong has over 23 million TEU in 2006. Here we consider all terminals in the Port of Hamburg for 2005 and selected terminals from Table 1 for Busan and Hong Kong in 2006. Eurogate is Europe's leading container-terminal and logistics group. Furthermore, jointly with Contship Italia, it operates sea terminals in the Mediterranean region. Six container terminals in Gioia Tauro, La Spezia, Livorno, Ravenna, Salerno and Cagliari, plus the intermodal network of the transport company Sogemar, are combined under the umbrella of Contship Italia S.p.A. of Milan (Italy). The largest terminal of them is Gioia Tauro, which handled 2.873 million TEUs in 2006 and 3.3 million TEU in 2007 as the leading transshipment centre in the Mediterranean. In the same time, the Port of La Spezia achieved a throughput of 0.99 million TEU while the Port of Livorno reached 0.4 million TEU in 2006. The Port of Salerno and Port of Cagliari had 0.24 and 0.65 million TEU in 2006, respectively. Contship Italia Group has developed large transshipment hubs as well as flexible regional gateway ports.

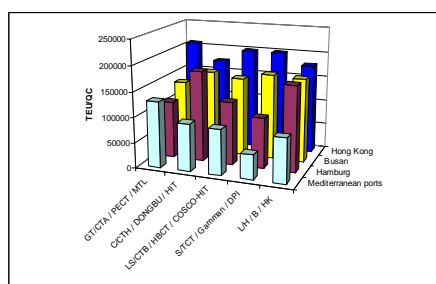


FIGURE 11  
TEU per QC of selected ports

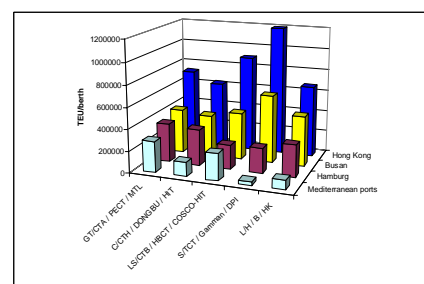


FIGURE 12  
TEU per berth of selected ports

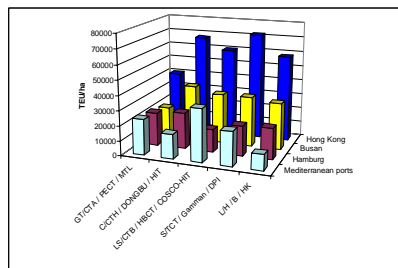


FIGURE 13  
TEU per ha of selected ports

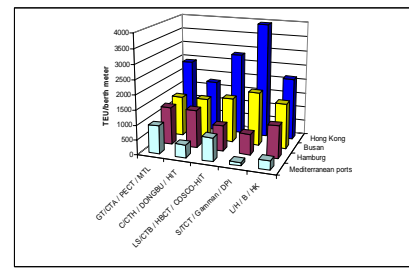


FIGURE 14  
TEU per m of berth length of selected ports

## 5. CONCLUSIONS

After analyzing the collected data, the results show great differences between selected ports and terminals. Far East berth and terminal productivity is significantly higher than in major European ports. In addition, containerization is well established in comparative regions. Average utilization of European ports and Contship Italia Group are lower than Far East ports as a whole. On the other hand, productivity is high and increasing in major northern European container terminals. Furthermore, relationship between container handling and land performance and current throughput of container terminals may be used to find the optimal capacity performance.

In summary, productivity is high and increasing in major European container terminals. This is a manifestation of the highly competitive nature of the business, with standards of operation forced upwards by the requirements of the shipping line customers. It cannot be said that productivity in the region is a manifestation of any lack of competitive pressures.

China with a high throughput performance presented through the huge improvements in ship operations over the past ten years came as a surprise, as did the performance achieved by an emerging new port such as Shanghai. Compared with major Far East ports, Chinese ports are relatively showing a steep growth and high throughput performances. This rapid increase of container volume is stemmed from the economic expansion and growing markets of China. From the perspective of resources per container terminal of China, each terminal has: above 3.5 units of QC (quay crane) per berth with around 300 m of quay length, 5.5 YT yard truck per QC, and 4 units of RTGC per QC. In addition, short storage period and cheap labor costs are also important factors to her high handling performance. But the possibility of productivity reduction coming from low service level due to the rapid container volume increase and the conspicuous obsolescence of facilities should be taken into consideration.

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# **Chapter 2**

Regional Issues in Logistics and Transportation



## LOGISTICS SERVICE PROVIDERS IN TURKEY: A PANEL DATA ANALYSIS

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**Abstract** — The companies competing in today's business environment are forced to re-engineer their supply chain management in order to meet the increasing needs of the customers. Today's trend for industrial firms is to have a variable cost system by receiving logistics services through outsourcing and focusing on core competencies. This study aims to analyze the logistics service providers sector in Turkey comprehensively and to reveal the sector profile clearly by comparing the data collected in year 2001 and 2007. For this purpose, initially, an empirical research study was carried out to assess the profile of companies operating as logistics service providers and the logistics services already being purchased by real sector and the nature of sector-specific services. The companies to participate in the research were selected so as to form a homogeneous distribution with respect to their turnover, number of employees and geographical locations, therefore aiming to achieve a complete portrait of the Turkish Logistics Providers Sector as a result of the research. The field study involves face-to-face interviews with 71 companies for the year 2001, and 101 companies for the year 2007. The results indicate that although the number of 3<sup>rd</sup> party logistics providers (3PLs) increase in total, when the number of different sectors they are providing services is analyzed, it is found that especially for the top served sectors, the number of logistics service providers is significantly decreased. This can be interpreted as the 3PL companies are focusing on a limited number of different sectors to provide services.

**Keywords** — 3rd party logistics providers, outsourcing, logistics activities, survey, Turkey

### INTRODUCTION

Organizations have been increasingly turning to outsourcing in an attempt to enhance their competitiveness, increase profitability and refocus on their core business. In the academic and practitioner literature, emphasis has shifted from outsourcing parts, components, and hardware subsystems towards the even greater unexploited potentials that intellectual systems offer. The motivations for outsourcing in any industry are driven by an ever-greater organizational pursuit to ensure cost discipline, whilst improving quality of service and delivery capability. However, as the outsourcing has become a popular mechanism for differentiation by contracting out the non-core activities, the differences in the motivations for outsourcing have emerged. This has been ignited by the debate as to what is core and what is non-core function. Outside vendors are regarded as specialists who can provide similar or better level of service at a lower cost than available in-house. However, through outsourcing, firms can also generate various non-financial benefits such as responding to environmental uncertainty in ways that do not increase costs associated with internal bureaucracy. Moreover, they can also focus on building their core competencies, while outsourcing the noncore activities to specialist vendors for both one-off and continual improvements. This is because firms are reported to have limitations as to the depth of specialist knowledge possessed by the suppliers [1].

Fierce competition in today's global markets, the introduction of products with short life cycles and the heightened expectation of customers have forced manufacturing enterprises to invest in and to focus attention on their logistics systems. This, together with improvements in communications and transportation technologies, has resulted in continuous evolution of the management of logistics systems [2].

The new century has shifted the importance of organizational functions and today's trend for industrial firms is to outsource those products and activities, which are not the company's core business. The

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international outsourcing has been referred to as one of the drivers that have made the world “flat” and with increase in international outsourcing, the sourcing debate has moved from what and how to outsource to what and where to outsource [3]. The importance of outsourcing varies among sectors. Outsourcing has grown by 52% for the period 1993–2003 for medium–high-tech sectors while the increase for low-tech sectors is much lower, only 19% [4].

Bendor-Samuel (1998) asserts that outsourcing provides certain power that is not available within an organization’s internal departments [5]. This power can have many dimensions: economies of scale, process expertise, access to capital, access to expensive technology, etc. Another possible benefit is that outsourcing provides companies with greater capacity for flexibility, especially in the purchase of rapidly developing new technologies, fashion goods, or the myriad components of complex systems [6], [7].

Likewise, by outsourcing logistics activities, firms can save on capital investments, and thus reduce financial risks. Investment on logistics assets, such as physical distribution centers or information networks, usually needs large and lump sum costs, which involves financial risks. Furthermore, the 3PL provider can spread the risks by outsourcing to sub-contractors.

As the world becomes more global and the boundaries between countries and cultures disappear, many developing countries, including also Turkey, are turning into attractive centers for international firms because of the geographical locations, low working fees, and high potential for market extensions. However a previous study shows that, in Turkey, outsourcing is still solely based on transportation [8]. As can be seen from this research many Turkish firms understand logistics services as taking the transportation order from the manufacturer and delivering the goods to destination points, without thinking about the warehouse design, the best location of the warehouse or inventory management. Such way of thinking concerns only one side of the subject and reduces the logistics services to a narrow transportation perspective.

This study aims to determine the current situation of outsourcing logistics activities in Turkey, which has a great potential for logistics activities among the surrounding continents because of its geographical location. An empirical research study was carried out to determine the types of logistics activities that are most frequently provided by the 3rd party logistics firms and to reveal the changes in the conjuncture if there are any. A questionnaire was prepared to examine the current situation as well as the future plans of Turkish 3PL firms in terms of logistics activities. Results indicate that most of the firms provide services for more than one industry; apparel, automotive and chemistry industries being the most frequently served. Another perspective of the study highlights the changes in the sector between 2001 and 2007.

## THE FRAMEWORK OF THE STUDY AND RESEARCH METHODOLOGY

This research presented here reveals the results of a subgroup belonging to a large logistics sector survey. The survey includes the four main groups of players operating in the logistics sector. These groups are: Logistics Service Providers, Logistics Service Customers, Logistics Equipment and Hardware Providers, and Information Systems Providers (Figure 1). This study focuses on the first subgroup, logistics service providers survey.

A field study involving face-to-face interviews with the companies operating in the logistics sector as service provider was performed for the research. In the field study, face-to-face interviews were preferred, rather than sending questionnaires by mail. The main reasons for this are the low rates of return for studies performed via mail, the lack of possibility to correct misunderstandings and the loss of the opportunity to obtain information that can only be achieved during an interview.

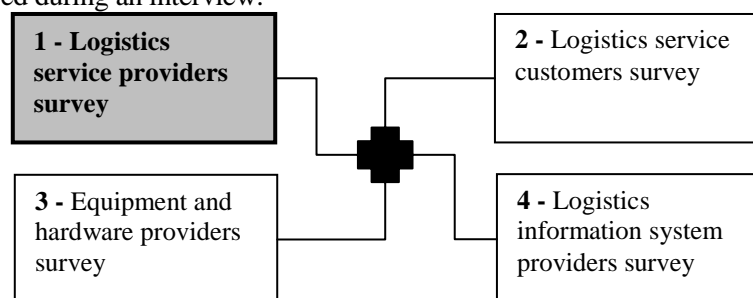


FIGURE 1  
Turkey logistics sector survey



The companies to participate in the research were selected so as to form a homogeneous distribution with respect to their turnover, number of employees and geographical locations.

The questions in the survey can be grouped under two groups, namely, profile related questions and logistics related questions. Profile related questions include industry in which the firm operates, duration of operation, number of employees, existence of a foreign partnership, and sales turnover. Logistics related questions include the cities that the 3PLs have offices and distribution centers, the services they provide, the sectors that the 3PLs provide special services (i.e. rack transportation for apparel sector), warehouse information, and perception about size of the logistics sector.

## RESEARCH FINDINGS

The questionnaire has sections on company profile, logistics services, warehouses, and number of employees (which can be analyzed under company profile). When two different respondent sets from 2001 and 2007 are compared with respect to how long they have been in business, it can be said that there had not been a significant change ( $p=0.975$ ) in the composition (Table 1). Approximately 70% of the firms have survived in the market at least 8 years or more.

TABLE 1

Operating year, status and capital structure, range of employees comparisons

Questions	Categories	2001	2007
<b>Operating year</b>	0-1 years	1.4%	2.0%
	1-2 years	8.5%	4.0%
	2-4 years	4.2%	9.9%
	4-8 years	15.5%	14.9%
	More than 8 years	70.4%	69.3%
<b>Firm status</b>	International company	38%	48%
	Local company	55%	48%
	Partner with an international company	7%	5%
<b>Capital structure</b>	Single partner	23%	18%
	Multiple partner	72%	80%
	Public company	6%	2%
<b>Range of employee numbers</b>	1-25	14%	28%
	26-50	17%	22%
	51-100	14%	17%
	101-250	15%	15%
	250-500	17%	6%
	More than 501	17%	13%

When the firm status is analyzed it has been found that 55% of the participant companies operating in the Turkish logistics sector have local status, 38% of the participants are international companies and 7% are companies with international partnerships in the year 2001. The fact that the re-engineering process of the Turkish logistics sector has started recently shows that Turkey is an attractive market for foreign companies. The ratio of international companies introduced to the Turkish market via partnerships with a local company, or fully independently, has reached 48% in a short time (see Table 1). Although the ratio of international companies increased to 48% in 2007 the partnership status of the participants indicates no significant difference in the percentage of firms that are international / local / partner between 2001 and 2007 ( $p=0.209$ ). neither the increase in percentage of international companies from 38% to 48% nor the decrease of local companies from 55% to 48% is found statistically significant. Similarly, the change in the percentage of companies that are partner with an international company is insignificant.

Another finding of the research on capital structures of the companies interviewed is that 72% in 2001 and 80% in 2007 have multiple partners. The ratio of single-partner companies is 23% in 2001 and 18% in 2007, whereas the ratio of public logistics companies is 6% in 2001 and 2 % in 2007. When the capital structure of the firms is compared regarding two survey years, there is no statistically significant ( $p=0.881$ ) change in the percentage of firms that are single partner, multiple partner or public company. The majority of the firms are multiple partners (see Table 1), which can be a consequence of high first investment costs of warehouses, distribution centers, and cargo fleet. When the range of employee numbers of the firms are concerned regarding the scale given in Table 1, there has been a significant change in the range of employees of the firms from 2001 to 2007. The percentage of firms which have less than 100 employees is increased from 48% in 2001 to 66% in 2007 ( $p=0.016$ ). It can be concluded that the firms prefer to work with less employees in 2007. While the percentage of firms with 251-500 employees is 18% in 2001, it is found that only 6% of the firms in 2007 belong to this range ( $p=0.014$ ). Meanwhile, the percentages of small scaled firms (with 1-25 and 26-50 employees) have also increased from 2001 to 2007. However, the only statistically significant change is observed for firms with 251-500 employees.

The most frequently provided services in 2001 are international land transportation Truck Load (TL) and Less than Truck Load (LTL), domestic land transportation (TL), warehouse, and distribution to customer warehouse. While no changes is revealed in the rate of provided services in 2007, the Project Transportation where transportation is designed according to customer's needs gains more weight and replaces warehouse in the rank of occurrence (Table 2).

TABLE 2  
The most frequently provided services

Service	2001	2007
International land transportation (TL)	86%	83%
International land transportation (LTL)	77%	67%
Domestic land transportation (TL)	72%	66%
Warehouse	72%	49%
Distribution to customer warehouse	70%	53%
Project Transportation	65%	53%

A further analysis has also been conducted to reveal the changes and as well as their direction in the services provided by the 3PLs. Table 3 shows that the provided services changed significantly from 2001 to 2007. A decrease in all these services is observed which can be interpreted as the 3PLs are now more focusing on providing core services that they are good at rather than providing numerous services to various sectors.

TABLE 3  
Significant changes in the services provided

Service provided	2001	2007	Significance
<i>Distribution to customer warehouse</i>	70%	53%	$p=0.025$
<i>Domestic land transportation (LTL)</i>	70%	44%	$p=0.000$
<i>Ship transportation</i>	58%	40%	$p=0.019$
<i>Air transportation</i>	69%	34%	$p=0.000$
<i>Distribution center</i>	52%	28%	$p=0.001$
<i>Cross docking</i>	51%	26%	$p=0.001$
<i>Reverse logistics</i>	46%	25%	$p=0.003$
<i>Bonded warehouse</i>	65%	38%	$p=0.000$
<i>Warehouse</i>	72%	49%	$p=0.002$
<i>Palletization</i>	59%	33%	$p=0.025$
<i>Shrinking</i>	56%	30%	$p=0.000$
<i>Labeling</i>	56%	33%	$p=0.002$
<i>Packaging</i>	55%	30%	$p=0.001$
<i>Quality control</i>	37%	19%	$p=0.009$
<i>Full export-import operations</i>	58%	36%	$p=0.004$
<i>Customs clearing</i>	59%	42%	$p=0.023$
<i>Operational reporting</i>	62%	37%	$p=0.001$

The services that have not changed significantly are; distribution to final consumption location, international land transportation (LTL and TL), domestic land transportation (TL), project transportation,

container transportation, railroad transportation, intermodal transportation, light assembly/disassembly, vendor managed inventory, collaborative forecasting and collaborative planning, and e-procurement.

*Sectors that 3PLs provide specific services, and the respective specific services:* Considering the sectors on which companies providing sector-specific services focus, it is obvious that the apparel sector predominates. The apparel sector is followed by automotive, food retail, chemistry, and medicine / health sectors, respectively. When we look at the top five sectors that the logistics service providers are providing special services (such as rack transportation for apparel industry of frigorific transportation for food industry), no change has been observed from 2001 to 2007. The only sector facing a considerable change in terms of sector specific services is apparel, in which the number of 3PLs providing special services to this sector is significantly decreased. Parallel to this, the rack transportation services have also decreased significantly from 32% in 2001 to 15% in 2007 ( $p=0.006$ ). *Sectors that the 3PLs are providing regular services:* In 2001, apparel, automotive, chemicals, machinery, computers/electronics sectors are indicated to be the sectors offered services by the great majority of the participants. In 2007, we see that computers/electronics sector is not anymore in the top five list being replaced by the construction materials sector. This result is not surprising considering the construction boom observed in those years between 2001 and 2007. The ranking of the sectors has also changed in 2007 as machinery, construction materials, apparel, automotive and chemicals respectively. When the data is analyzed to find out whether the change in the number of 3PLs is significant or not, it has been found that there is a substantial decrease in apparel, automotive, chemistry and computers/electronics sectors. Although there has been an increase in the percentage of 3PLs for constructing materials sector from 62% in 2001 to 70% in 2007, this increase is not statistically significant (see Table 4). For computers/electronics sector, a statistically significant ( $p=0.003$ ) decrease is found for the percentage of 3PLs providing services to this sector (from 69% in 2001 to 46% in 2007). Similarly apparel and automotive sector has witnessed a significant decrease (see Table 4 for significance values).

TABLE 4  
Top sectors served and significant changes

Top sectors for 2001 and 2007	2001	2007	Significance
<i>Apparel</i>	83.10%	63.35%	$p=0.010$
<i>Automotive</i>	80.28%	60.40%	$p=0.005$
<i>Chemicals</i>	76.06%	56.44%	$p=0.008$
<i>Machinery</i>	71.83%	71.29%	$p=0.938^*$
<i>Computers/electronics</i>	69.01%	46.53%	$p=0.003$
<i>Construction materials</i>	61.97%	70.30%	$p=0.256^*$

In order to calculate the size of the logistics sector and its growth rate during recent years, the participants were asked about their sales turnovers, the rates of change of turnover relative to previous year and turnover expectations for the next year. The reluctance for providing sales turnover information has somewhat decreased from 2001 to 2007; i.e. 66% of the firms reported their sales turnover in 2001, while 88% of the firms report their sales turnover information in 2007. Once the outliers have been discarded, the average of sales turnover for 2001 is 27,665 YTL, and the average of sales turnover for 2007 is 36,125 YTL. However, this difference is not found statistically significant ( $p=0.510$ ). Another question directed to the participants was about their estimates on the size of current Turkish logistics market. The estimates of the participants have risen from 2-4 billion in 2001 to 12-14 billion USD in 2007. The firms are also compared with respect to their strategic behavior. In this section they are asked about whether their vision and mission is determined, their strategy is reviewed regularly, and their strategic goals are documented. In 2007, an additional question on whether all employees are informed about the mission, vision and the strategy of the company or not is asked as well. The answers to these questions are given on a 1-5 scale, depicted in Table 5.

TABLE 5  
Strategy related answer options

Answer	Point
Not implemented	1
Planning to implement	2
In preparing stage	3
Partly implemented	4
Fully implemented	5

When the question on whether vision and mission are determined is analyzed, it is seen that in 2001, the firms mentioned that their vision and mission are partially implemented (average: 4.26), while in 2007, they answered as they are at the preparation stage (average: 3.87). There has been found statistically significant difference ( $p=0.043$ ) between these answers. In fact, since the logistics sector market is enlarged in 2007 when compared to 2001, many new players which are at an earlier stage of strategic planning studies entered the market. When the answers to “strategy is reviewed regularly” question is analyzed, it has been found that there is no statistically significant difference between firms that are at the partly implementation stage between 2001 and 2007 (average: 4.26 in 2001 and 4.00 in 2007 respectively,  $p=0.162$ ).

Similarly there has not been found a statistically significant difference for documentation of strategic goals, where firms are both at partly implementation stage (average: 3.91 in 2001, and 3.49 in 2007,  $p=0.063$ ).

## CONCLUSION AND FURTHER SUGGESTIONS

The changing nature of work reflects a major shift in the way work has traditionally been done. To remain competitive and to ensure continued survival amidst such ‘hypercompetitive environment’ firms are attempting to devise new strategies. Research has found that under such circumstances firms disintegrate their business functions and increase outsourcing **Error! Reference source not found.**

The use of outsourcing as a strategic device has been structured on the idea that certain functions such as data handling, customer relations management and information processing are common activities among different industries and thus can be decoupled from their respective value chains. Consequently, firms can focus on their core competencies to develop superior capabilities in order to outcompete other firms in the same industries while externalizing the decoupled or disintegrated functions.

In the literature outsourcing has been identified as one of the most important components of ‘flexible’ firms that can respond quickly to unanticipated threats and opportunities of the market. There are abundant examples in the computer and apparel industries, where industry leaders such as Microsoft, Dell Computers, and Reebok have established the advantages of outsourcing peripheral functions while gaining flexibility and speed through their flatter organizational forms.

The competition in the logistics sector is increasing and causing 3PLs to provide a limited number of services. Similarly, the number of different cities that a single 3PL has offices as well as distribution centers is decreasing dramatically which is also an indicator of more focusing on regional markets rather than providing services for the whole country as well as the European Union. However, since the logistics market is growing in size there are more players in the market, and hence, they have not completed their strategic planning issues yet (or they are at early stages of the strategic planning on the average).

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# MILESTONES IN THE PROCESS OF SURVEY PREPARATION FOR THE LOGISTICS SECTOR: CASE STUDY FOR ISTANBUL, TURKEY

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**Abstract** — This paper presents the stages, from beginning to the end, of the process of survey preparation in order to collect related data for the analyses of the logistics sector in Istanbul, Turkey as a case study. For such a study, we first determined the study scope which had two aspects: One was the determination and classification of the actors in the logistics sector. The other was the determination of the survey scope which included the basic information to be collected regarding the actors in the logistics sector and the design of survey questionnaires for targeted recipients. Later, survey methodology was determined which included a) establishment surveys which are face-to-face interviews with representatives of the actors of the logistics sector, b) vehicle classification counts for 3-day-24-hour exiting and entering at the gates the establishments, c) truck driver surveys at the same vehicle classification locations as well as at outbound external stations (4 highway segments and 2 ports' gates), and truck driver diaries for freight/goods distribution companies. In addition, trip diaries are distributed to truck drivers of some of the actors of the sector. Sampling framework and survey instruments were designed considering almost all parties of the logistics sector. The system operations among these actors were determined by investigations through many interviews, meetings and interactions with the sector's members. The study scheme was designed with the input of all these information and data regarding the system operations of the logistics sector in Istanbul. By this scheme, various types of questionnaires were designed for different groups of the system's actors. Questionnaires were distributed first to a group of actors of the sector in order to evaluate the quality and understandability of the survey questions.

**Keywords**— logistics planning, traffic counts, truck/goods survey, urban planning, Istanbul

## 1. INTRODUCTION

Trucks are not allowed to operate along major arterials and highways of the city of Istanbul during the peak-hours, especially along the two bridges crossing the Bosphorus which divides the city into two parts, i.e., East and West parts. This application affects manufacturers, commodity transporters and goods forwarders since it reduces the daily crossing capacity through the city between the two sides. The reason behind this decision given by the city management is that the truck/freight traffic will severely affect the passenger traffic along the already congested highway network during rush hours. However, no such analysis has been made to support or deny this claim. For this reason, we think that local freight and truck movement data collection efforts can provide more representative and accurate data to support or deny such claims as well as to perform the freight/goods movement analysis and to support urban planning process for the future of the city [1]. Forecasting goods movement and truck volumes are a necessary prerequisite for the development of travel demand models to evaluate urban and regional transportation plan alternatives [2]. Freight transportation planning for urban areas is not performed as usual as passenger transportation planning since most planners and engineers working for public agencies are not trained in freight planning and related analyses [3]. The only comprehensive source of information on urban goods movement published in recent years belongs to a book by Ogden [4].

### 1.1. Reasoning of the Study

There has been a growing interest in the consideration of freight/goods movements in transportation planning processes because of the critical role played by freight transportation in

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regional economic growth and development as well as the sectors' capacity for fulfilling the regional employment needs [2], [3]. During the last two decades, freight demand models have been developed and documented [3], [5]-[8].

No credible data source regarding commodity and goods movements have been available for the city of Istanbul, Turkey until recently. As well in abroad there have been very few truck surveys that collect trip data for internal freight/goods movements [2]. Both due of the lack of inventorial database and the lack of attention to the subject, logistics and goods movements have not been thoroughly studied from the perspective of urban or city planning. It is a pity that though a logistics system greatly affects urban transportation and land use systems, which are the basics elements of urban systems, the subject has not been studied and paid attention to at all, rather than the definition of zonal land uses with respect to warehouses, ship-dockyards, container lots, and so on. Without having such data regarding logistics and goods movements, urban transport decisions cannot be applied successfully. In order to include the analyses of logistics and goods movements in urban planning and also in order to do logistics planning, data with respect to goods and truck movements need to be available. But, this has not been the case for the city of Istanbul until recently. No data with respect to logistics and freight planning have been available for Istanbul until recently. For this reason, a comprehensive study was planned and initiated for the first time in Istanbul, Turkey, in 2007 in order to analyze all logistics and freight movements within and through the city. By this study, an x-ray of major logistics movements has been taken and an introduction to logistics planning has been realized using these data in the Istanbul's 2023 Strategic Regional Plan with 1/100.000 and 1/25.000 scales. These data with proper updates can also be used for future planning studies. Those logistics analyses did not find their own places in urban plans in the past will hopefully be the basic inputs to all planning studies from now on.

## **1.2. Purpose of the Study**

The purpose of this study is to document the stages, from beginning to the end, of the process of survey preparation in order to collect related data for the analyses of the logistics sector in Istanbul, Turkey as a case study. By this effort, a comprehensive inventorial database with respect to goods and logistics movements in Istanbul by time of day, day of week, type of goods and truck, goods size/weight, and the land use that generates logistics movements was aimed to create.

## **1.3. Methodology**

Types of data collection methodologies were utilized in the study named as follows:

1. Logistics sectors' establishment surveys,
2. Vehicle classification and passenger counts,
3. Roadside intercept surveys for all vehicles at major external stations (highway and freeway locations) of the study area,
4. Survey of truck drivers intercepted at the logistics establishments, and
5. Travel diary surveys for truck drivers and trucking company surveys.

Before determining activities and capacities regarding goods movements of the members of the logistics sector, questionnaires were prepared and distributed for pre-testing to some sector members. After this pre-test, forms were completed by the randomly selected sector members by conducting a face-to-face interview by the trained interviewers.

Vehicle classification and passenger counts (included pedestrians and bicyclist) were done by trained individuals at the gates of a sample of establishments during the same time period for 24 hours. Though 3- or 7-day counts were planned at the beginning of the study, budget constraints confined us to be fine with one-full day. To overcome this limitation and extend one-day observation to a several-day traffic flow profile, we developed a new-count sheet to record "stated traffic flows" based upon partial observations for the counted and the other two uncounted days. Based upon the existence of a meaningful correlation between the actual and the stated traffic flows, the stated traffic flows for the other two uncounted days were factorized to replicate actual traffic counts.

Roadside intercept surveys and truck driver surveys were carefully done by trained persons. Roadside intercept surveys were done from Wednesday noon until Friday midnight at six external

stations on exiting lanes though truck driver surveys were at the gates of a sample of establishments for 24 hours during the time of vehicle counts.

Lastly, truck driver surveys were done by trained individuals counting private cars, buses, motorcycles and cargo vehicles including minivans, small and large trucks and trailers with or without goods in the vehicle entering or exiting at the same gates where traffic surveys were done at the same time period for 24 hours. Cargo vehicles were sampled by their arrivals; i.e., the first vehicle stopped at every 10 minutes during a 30-min. period and the driver was asked for vehicle's odometer, plate number, origin or destination for the load related to the surveyed land use, departure time from his origin and approximate arrival time to his destination, and the type and size of the goods.

#### **1.4. Scope**

This study is designed to be quite comprehensive since its purpose is to create a detailed inventorial database with respect to all goods movements and the land use generating these movements within the city of Istanbul (size=5712 km<sup>2</sup>). Within this context, it is extremely important to identify the actors who are creating these goods movements; mainly, manufacturers, freight forwarders, shippers, storages, wholesalers and retailers. These actors are displayed in a scheme of the system as seen in Figure 1. There are many elements constituting the urban logistics system; actually, all activities can be considered as a part of the logistics system. However, if we want to draw a flow chart of this system at a basic level, at the top of the system manufacturers are located on organized industrial and agricultural campuses or spread all over the city. Later, goods were transported to transfer centers, such as storages of shippers, warehouses or wholesalers from where they were manufactured. Following that, goods and products were transported to transfer centers such as ports and harbors, customs, cargo terminals. Final destinations are the markets where they reach to customers at retailers.

It is highly important to correctly determine the major elements of the logistics system, which we call the actors of the study. These actors include organized industrial campuses, light industrial areas, boat construction shores, port and harbors, shippers, wholesale markets, transport depots, warehouses, container lots, customs, bonded warehouses, distributors, and retailers.

## **2. STUDY DESIGN**

The study design used in this paper is described in the following sections.

### **2.1. Analysis of the Logistics System: Actors of the System**

In this section, the issue is to correctly describe the relationships among the actors, and between them and the market. This is extremely important since by this relationship it is possible to lead the study to the right direction and make the descriptions of the sector's actors and the distinctions among them properly. The identification how the logistics system created by the system's actors is operating in Istanbul was made possible by a comprehensive study. This identification was achieved by proper correspondences with the major actors of the system. By these correspondences, we were able to learn how the system operates and what the actors do in detail. Thus, main components of the goods movements in Istanbul were determined and study scope was defined definitely as possible. By the definition of the system's operation, it was possible to stratify the actors by business and by their positions taken in the system. Then, actors were placed into groups by these definitions. By these stratifications, response rates to survey questions were observed at very high percentages.

### **2.2. Sampling Frame: Determination of Populations and Samples**

Another important issue is to define populations for each actor groups as correct as possible. By this way we can know the rate of representation of the sampling group in Istanbul. In this case, we used various databases created for the city of Istanbul by various departments of the metropolitan municipality of Istanbul such as housing, land use, mapping, transportation, recreational parks, city and planning departments as well as the departments of the central government such as the Ministry of Education. These databases include the data regarding housing, business and service sectors, industrial sector, and parks and cemeteries.

Spatial distribution of the system's actors in Istanbul is considered by designing questions. Many actors have branches or warehouses in several parts of the city. Branches belonging to same actors are included in the database as either separate entities or one entity. For example, an enterprise X has a management office at one location, at a different location X has a factory that has production lines, and at different locations it has four warehouses. This X is included in the database as either one entity or six entities (one management office, one factory and four warehouses). Also, the functions of these entities are different from each other. The office building has managerial activities, the factory has production or manufacturing activities and the warehouses have storage activities. It is very possible to have the X in three different lists or in just one or two lists. It is again very possible to have the X unlisted at all but was encountered at field screenings. All these issues were handled properly while preparing population lists. For this reason, we designed the questionnaires to ask if the selected entities have other branches, warehouses or managerial offices at other parts of the city or the country. By considering the possibilities of compound or individual entities, for example some factories have warehouses and some others do not. The issue is whether these compound entities or others do business significantly different regarding the movements of goods and logistics. If there are differences between such different units, then all branches of a single entity must be surveyed separately. However, this increases the time and personnel expenditures. Another approach is to increase the sample size in order to lessen the effects of such discrepancies within the sample. To keep it in mind, by questionnaires information regarding the capacity, type and size of the business is collected only for the visited locations. In the case of the entity of X, if we visited only the factory, the questionnaire is filled out for the factory, not for the warehouses or the managerial office. If we preferred to receive information for all entities belonging to the X, for some cases the questionnaire is filled out only for the visited locations and some other cases for all entities, and in this case we could not know which information belongs to which unit. To help to clarify such cases, we developed and used the third type of questionnaire at the managerial locations. By this questionnaire, information regarding capacity, type and size of the business is collected for the visited location as well as for one entity for the similar entities, such as at one of the four warehouses and the information for the visited warehouse is extended to the rest three by using size and capacity information related to the business.

### 2.3. Survey Design

Considering various types of actors, two approaches were considered for the design of the survey questionnaires. First approach was to prepare a long and comprehensive questionnaire book and have the actors fill out the same questionnaire from beginning to end. In this case, the sections and questions that are not related to some actors can be left blank or checked with a choice of "not applicable." However, such unanswered questions with lack of information can be mixed with others that are really "not applicable." If every questions has a last choice of "not applicable," this can make the response time of interviewees longer, which can limit the possibility of the survey's application. An advantage of this type of survey applications was its easiness for the analysis of answers by having a single type of data coding system. If we do not want all interviewees read all questions, we might have more directions to advise skipping some questions for some type of interviewees. In this case, interviewers might observe a difficulty to apply the forms and a strict training must be given to interviewers frequently during the course of the study. In the second approach, the system's actors are stratified and grouped by their businesses and by their positions taken within the systems. For each groups, different survey forms are designed to ease the above difficulties mentioned in the first approach. By this approach, the forms are easily completed because unrelated questions are not included in the forms, and by having fewer questions, responses of the interviewees are taken under high enthusiasms. In this study, the second approach was utilized in order to make this stage successful.

#### 2.3.1. Grouping the System's Actors

In the analysis of the current logistics system, we have observed that some actors get together at certain locations by their decisions, if necessary, with the changes in planning decisions by the planning authority. These actors do their business by their own management policy. This is just the case in the transport depots and shippers in Topkapı. This is one campus and holds 140 firms acting as



freight forwarders to in and out of Istanbul. These firms were shown this location as an urban planning decision and future planning decisions will be enforced to all of them and information regarding all these individual firms can be received by their management offices. Thus, such land uses are considered to be managed by “organized management offices.” The management of organized industrial campuses is one of such examples to these organized management offices. For such campuses, we have developed two types of survey questionnaires: 1) the first one is for individual firms and units within the organized campuses, and 2) the second is for their management offices. By the first questionnaire, we have collected information regarding the business and capacity of individual firms and units. The second from targeted the information regarding the whole campus and the businesses and capacities of their members as a whole. Lastly, there is the third type of the sector's actor, to which the first type of survey cannot be applied. For those, we have developed a third type of questionnaire form in order to collect information regarding the business and capacity of them. These actors are not manufacturers, wholesalers, or retailers but organizational institutions of them, customs offices, freight forwarders or goods distributors within the city.

### **2.3.2. Who Will Answer the Surveys?**

After defining and groping of the actors, the issue is who answer the survey and what their positions will be. The questionnaires were answered by general managers, vice managers and logistics managers. If these people are not present at the time of visit, another appointment is taken. However, at some cases these positions are taken by less educated people, and in one case during pretests a representative of a warehouse did not know whether he was working at a bonded warehouse. Thus, explanations are written in an informal language as possible and academic or formal language is not used when the opposite is possible.

### **2.3.3. Design of the Forms**

Design of the surveys forms included grouping the same type of questions and creating a logical flow from beginning to end. For example, questions seeking information regarding the identification are placed at the beginning and some others seeking financial information are placed at the end of the forms as is usually known that financial information might not be disclosed to other competitors. Thus, easy questions came first and the difficult or sensitive ones came later in order not to let the interview discontinue earlier.

Flow charts of the questionnaires helped a lot to decide how to use the information sought by each questions and how to relate them each other, if necessary. By this, some questions sought detailed information and some other did not. Also, each question is evaluated from the perspectives of the benefits that will be gained if asked, such as more information to make detailed analyses; and of the losses that will be lost if not asked, such as longer times and more personnel to complete the surveys, and tiring interviewees and rejecting to continue. Especially these losses might harm the dependability of the surveys. Thus, gains and losses by each question are discussed by professionals before and during the surveys based upon the answers received.

The flow chart of the questionnaires included the following groups of questions:

1. General information regarding the entity,
  - a. Name, address, phone and fax number, email and website.
  - b. Date it was established at the site visited
  - c. Field of business that is involved in
    - i. Major field
    - ii. Minor fields
2. Size of land use
  - a. Types and size of buildings and land uses
  - b. Capacity use for each building and land use
3. Number and size of freight/goods movements
  - a. By month of year, day of week, and time of day
  - b. Type and size of vehicle, and freight/goods type
4. Number and size of vehicle movements
  - a. By month of year, day of week, and time of day

- b. Type and size of vehicle, and freight/goods type
- 5. Capacity related to the sector
  - a. Quality of the business
  - b. Satisfaction of customers
- 6. Current employment and future personnel needs
  - a. By education, profession and experience
- 7. Financial Situation during the last year
  - a. Income and expenditures
  - b. Benefit/Cost ratio

#### **2.3.4. Traffic and Truck Surveys**

After the logistics sector (establishment) surveys were completed, vehicle classification and truck surveys were conducted. Traffic and truck surveys were conducted over a smaller sample than the establishment surveys were. The sample size for traffic and truck surveys is about 10 percent of the sector surveys.

#### **2.4. Difficulties Observed During the Study**

Some difficulties were observed during the study because the logistics sector is very huge and extensive. Though the efficiency of the sector is not truly within the scope of this study, some questions to disclose the time of duration of trucks for loading and/or unloading within each land use are designed and this design is failed, for example, at wholesale markets because some trucks spent more than 24 hours, even 2-3 days at such land uses. These cases greatly increased standard deviations of the asked variables. However, by this question though it is aimed to disclose the time spent for the operations of loading and unloading and to investigate reasons of such inefficient operations, such unusual cases distorted the averages of the asked variables. By analyzing the reasons of inefficient operations, the logistics system will be commented on in more details and necessary precautions will be taken for the optimization of the system. Though possible answers for the question asked are expected to be a couple of hours, the answers to it received at the wholesale markets are 2-3 days.

#### **2.5. Solutions for Successful Designs**

First of all, type of data needed for the study must be determined. Based on the type of data required, volume of data must be decided. Secondly, time, personnel and cost must be projected for such type and volume of data. Types of equipment and human resources required to perform data collection dictates the total cost of the study. Sometimes, automated data collection methods such as loop or radar detectors hinder details of trip and vehicle classification data. For this reason, manual data collection methods might be chosen. If the study is conducted by the regional planning agency, such as the metropolitan municipality's transport department as in this study, other local as well as central government agencies cooperate easily to make the study successful as desired.

For the success of the surveys, level of detail must not exceed beyond the scope of the study. This increases the cost and makes the interviews real burden on the shoulder of interviewees and they may give up answering the questionnaires as long and complex questions keep coming

### **3. CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH**

This paper summarized the purpose, scope, methodology, and stages of the study of logistics and goods movements as well as the things that need to be careful about while completing such a study. As a conclusion, such a comprehensive study that included analyses for urban planning is the pioneer of its kind as well as the comprehensive as possible. Since it is the first of its kind, possibly it includes some possible faults and errors in its measurements and analyses. Some of them can be avoidable by future updates. Some errors come from the methods utilized, which are, for example, due to human errors in traffic counts and some other are from the nature of questions taking place in the questionnaires. However, by the study an inventorial database of the logistics in Istanbul will be documented and the analysis of the data will be used for the purpose of urban planning. Even, regional

logistics plans are considered to be conducted. This study will be a good example for the same studies in the future.

As a recommendation for future research, we strongly suggest electronic vehicle counting by the analyses of video images. In this study, we used the video images and visually extracted data by trained personnel in order to control manual traffic counting. Secondly, we opted out recording plate number of the vehicles during counting since it increased the time and human resources incredibly, well beyond existing resources of the study. However, via video imaging methods, which are currently under development by a company of the Istanbul's municipality, it is possible to track vehicles entering the boundaries of the land uses that are the subject of the study but not directly related to this location can be excluded from the analysis. Also, by tracking the vehicles which are related to these locations studied, it can be possible to determine how long they occupied the parking locations within the land uses.

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# **Chapter 3**

Education and Training in Logistics and Transportation



# EDUCATION IN TRANSPORT AND LOGISTICS IN AN AGE OF GLOBAL ECONOMY.

Yücel Candemir<sup>1</sup>

**Abstract** - It appears that any country which ignores research and, therefore the competent human resources to carry out it, is doomed to be the underdog in the coming age of the 21<sup>st</sup> Century. Apart from other sectors of the economy, the logistics and transport sectors are to be scrutinised as specific sectors in this regard. There we face the need for a special study of a proper “Transport & Logistics Education” in the developing part of the world, on a comparative basis. The aim of this paper is to discuss this.

**Keywords** — Education - Knowledge Capital - Knowledge economy – Globalisation - Transport System

## 1. WORLD ECONOMY AT THE THRESHOLD OF NEW MILLENNIUM

Since last quarter of 20<sup>th</sup> Century the world economy is passing through a transformation process to be portrayed with a strong stress on technological development on the one hand and serious environmental problems at unprecedented levels on the other. These two elements, technology development and the cost of development in general, environmental deterioration, surpass all the other factors in designing development policies today.

These twin developments take place simultaneously within a context of the so-called process of globalisation. “Globalization is an ongoing trend. Although the benefits of globalization for developing countries are sometimes doubted, globalization is still seen as a prerequisite for further development. It can be interpreted as the growing economic interdependence of countries worldwide through the increasing volume of cross-border transactions in goods and services and variety in traded goods and services, through larger international capital flows and also through the more rapid and widespread diffusion of technology. It affects trade patterns, capital flows and location choices of firms at a regional and global level.”<sup>2</sup>

In an age of intensified global movement, accelerated technological development and challenges of intrinsic environmental troubles (global warming, climate change and the changing demographic structure in the world as well as the widening gap between the richest and the poorest), the designing and implementation of appropriate (sustainable) development policies gain a high level of priority in the agenda of today’s world.

“Capitalism is undergoing an epochal transformation from a mass-production system where the principal source of value was physical labour to a new era of innovation-mediated production where the principal component of value creation, productivity and economic growth is knowledge and intellectual capabilities. Capitalism in this new age of innovation-mediated production will require deep and fundamental changes in the organization of enterprise, regions, nations and international economic and political institutions. Survival in this new era will require the development of new organizational forms and systems, such as teams and new incentive systems, which decentralize decision making, mobilize intellectual capabilities, and harness the knowledge and intelligence of all members of the organization.”<sup>3</sup>

As the very movement of globalisation itself has happened before, today we face a new stage in this process. The last wave is distinctive in that

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<sup>2</sup> ARJAN LEJOUR, Globalization and the Global Environment: Four Quantitative Scenarios. CPB Netherlands Bureau for Economic Policy Analysis. 10 February 2003

<sup>3</sup> R. FLORIDA & M. KENNEY, The New Age of Capitalism. Innovation-mediated production. *Futures*. July-August 1993. p.637.

- (a) *“First, and most spectacularly, a large group of developing countries broke into global markets.*
- (b) *Second, other developing countries became increasingly marginalised in the world economy and suffered declining incomes and rising poverty.*
- (c) *Third, international migration and capital movements .... have again become substantial.”*<sup>4</sup>

As an indication of the effect(s) of globalisation process we can perhaps look at the change in world trade on a comparative basis. Between 1950 and 2004 world trade has grown 22-fold, from \$ US 375 billion to \$ US 8 164 billion.<sup>5</sup>

However, a global financial crisis at unprecedented dimensions gaining momentum makes the analysis of the world economy a controversial one. As it is really difficult to forecast the future of the globalisation clearly, the very presence of the globalisation movement with its existing domain is a *fait accompli* which we cannot / should not overlook.

## 2. PROSPECTS FOR THE FUTURE: ECONOMIC TRANSFORMATION

Whatever the developments into the future may take direction we can safely predict that the importance and effectiveness of one principal instrument of economic development, alongside with others, will keep its legacy: the technological competence of the countries. Economic development results from an assessment of the development objectives with the available resources, core competencies, and the infusion of greater productivity, technology and innovation, as well as improvement in human capital, resources, and access to large markets. Here, with an ever increasing impetus, technology production and technology development play a distinctive role in the process.

Economic development transforms a traditional dual-system society into a productive framework where markets can function for a betterment of the whole sections of the society. This picture turns into a more promising one as we transfer it from a national / regional level into a global one.

In this process *research* and *knowledge / knowledge economy* are the keywords to solve the puzzle. If we refer to the goals set by the European Union to face the challenge(s), knowledge, innovation and education turn out to be the tools of EU policies. The Lisbon strategy to make the EU *“the most dynamic and competitive knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion, and respect for the environment by 2010”* was adopted by the European Council in 2000. *“Supporting knowledge and innovation”* has been put in the first place by the EU Commission among the (eight) *key measures with a high European value-added*. In parallel with the *Barcelona European Council* which reviewed progress towards the Lisbon goal in 2002, the *European Research Area*, ERA, has contributed to better and more investment in R&D. *“To reach the Barcelona objective, research investment in Europe should grow at an average rate of 8% every year, shared between a 6% growth rate for public expenditure and a 9% yearly growth rate for private investment. This is ambitious yet realistic given the strong support given to the objective.”*<sup>6</sup>

## 3. KNOWLEDGE ECONOMY AND THE HIGHER EDUCATION SYSTEM

At the dawn of the new millennium, the roles attributed to the sciences seem to be changing hands. According to the British weekly, *The Economist*, *“There is in biology at the moment a sense of barely contained expectations reminiscent of the physical sciences at the beginning of the 20<sup>th</sup> century. It is a feeling of advancing into the unknown and that where this advance will lead is both exciting and mysterious.”*<sup>7</sup> In a sense, it will not be wrong to claim that there will not be a room in the new map of the world in the near future for the nations who cannot produce and develop technology. This will lead us to the conceptual boundaries of a knowledge society / economy.

<sup>4</sup> The World Bank, *Globalization, Growth, and Poverty*. A WB Policy Research Report. Washington, DC 2002.

<sup>5</sup> WTO, *International Trade Statistics*, 2005

<sup>6</sup> *Investing in research: an action plan for Europe*. COMMUNICATION FROM THE COMMISSION. Brussels, xxx COM(2003) yyy final

<sup>7</sup> “Biology’s Big Bang”, *The Economist*, June 16th 2007.

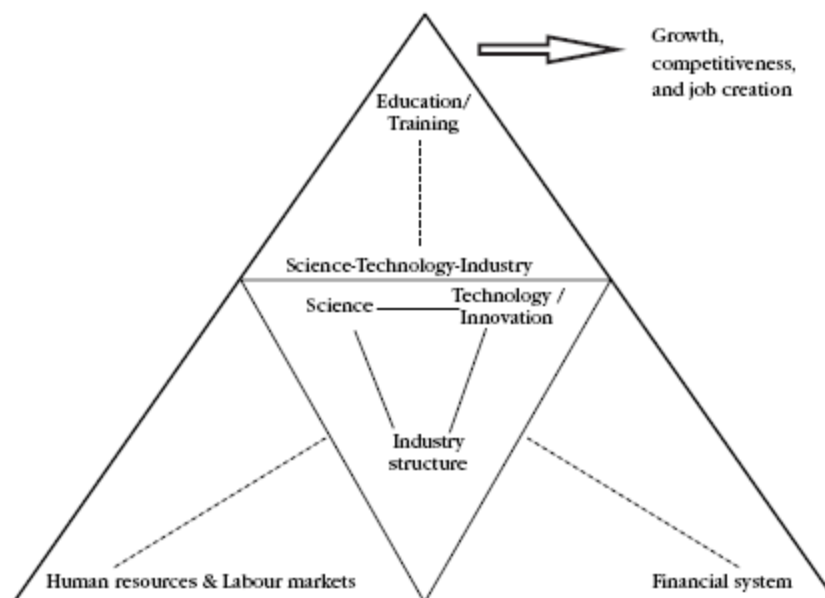


*“The Knowledge Economy is emerging from two defining forces: the rise in knowledge intensity of economic activities, and the increasing globalisation of economic affairs. The rise in knowledge intensity is being driven by the combined forces of the information technology revolution and the increasing pace of technological change. Globalisation is being driven by national and international deregulation, and by the IT-related communications revolution. However, it is important to note that the term ‘Knowledge Economy’ refers to the overall economic structure that is emerging, not to any one, or combination of these phenomena.”<sup>8</sup>*

Referring again to EU policies, the official documents of this giant underline the importance of knowledge: *“In the long run, however, the economic performance of countries is also strongly determined by knowledge-related factors (e.g. technical change and human capital). In particular, R&D and technological innovation have contributed substantially to the strong US economic performance over recent years. More generally, the contribution of knowledge investments and activities to employment, productivity and economic growth has been emphasised in many studies”<sup>9</sup>.*

The figure below taken from the same study depicts the interaction between different institutions in a country that individually and jointly contribute to the production, diffusion and utilisation of knowledge. In this system, science, technology/innovation and industry are central but not sufficient to ensure economic growth, competitiveness and job creation. The education and training system, human resources and the labour market, and the financial system – all have a substantial impact on the performance of ‘Science-Technology-Industry’.

Figure 1 The Science, Technology and Innovation system and its constituting building blocks



Source: DG Research

Data: Adapted from Amable B., Barré R. and Boyer R., "Les systèmes d'innovation à l'ère de la globalisation", Economica, Paris, 1997, p. 127.

Key Figures 2007

Further in this sphere of interest, another Commission Report<sup>10</sup> reads as *“The creation of a Europe of knowledge has been a prime objective for the European Union since the Lisbon European Council of March 2000. .... Given their central role, the creation of a Europe of knowledge is for the universities a source of opportunity, but also of major challenges. Indeed universities go about their business in an increasingly globalised environment which is constantly changing and is characterised by increasing competition to attract and retain outstanding talent, and by the emergence of new requirements for*

<sup>8</sup> John Houghton and Peter Sheehan, **A Primer on the Knowledge Economy**. Centre for Strategic Economic Studies Victoria University

<sup>9</sup> European Commission, **Key Figures 2007**. EUR 22572 EN

<sup>10</sup> Commission of the European Communities, **The role of the universities in the Europe of knowledge**. Brussels, 05.02.2003 COM(2003) 58 final

*which they have to cater. ... To implement the Lisbon agenda, the European Union has embarked upon a series of actions and initiatives in the areas of research and education. One example is the European area of research and innovation, to achieve which fresh perspectives have just been opened up<sup>3</sup> and, in this context, the objective to increase the European research and development drive to 3% of the Union's GDP by 2010."*

All these documentation serve to put forward that education in general and the higher education in particular is a *sine qua non* for instituting a knowledge economy for our age.

#### **4. THE ROLE OF TRANSPORT AND LOGISTICS NETWORKS IN THE NEW ECONOMY**

As global movement and global competition dominates the agenda of the world economy, the need for an *efficient transport and logistics design and management* is a growing theme for the foreseeable future in today's world. In this process, *strategic decision-making* come to the forefront as a major theme in transport and logistics management. "*Strategic decision-making in this sense represents a complex set of trade-offs of key challenges and associated (perceived) benefits and costs to the business. Active market and institutional forces changing at a fast pace present challenges to the fields of transport and logistics management*".<sup>11</sup>

The current growth trends in the transport sector have to be radically changed and reversed. For this to happen, there needs to be a strong commitment to the objectives of sustainability at all levels of transport policy-making. The transport sector has to go through a substantial policy shift if it is to comply with the objectives of sustainable development.

Such a policy shift has taken place in many parts of the world, with sustainable transport becoming an integral part and an indispensable objective of most national and supranational policy documents. There is broad agreement now that a more balanced transport system needs to be put in place, which requires a significant modal shift and inter-modality on major transport corridors. This requires not only a good level of policy knowledge but also advanced management skills in order to encourage an interconnected, intermodal, interoperable transport system, which can both help reduce petrol-dependency, emissions, congestion and bottlenecks, and at the same time ensure and strengthen competitiveness. In addition, urban transport policy is another major area where improvements are essential for better accessibility, mobility, environment, and quality of life. Public transport systems and non-motorised modes of transport are to be improved in order to encourage the use of these more environmentally friendly modes and to promote equity in transport opportunities that is to ensure accessibility for all. Such improvement schemes are increasingly being introduced together with restrictions on car usage, such as congestion charging, parking control and management, pedestrianisation, car-free areas, etc. While such transport policy measures have become widespread, there is also increasing awareness that these problems can be solved through land-use policies that can influence travel behaviour and attitudes towards car usage. In addition to macro policies for urban growth management, such as the compact city, policentricity, etc., neighbourhood design approaches to influence travel behaviour received significant emphasis, with much research on designing transit-oriented or pedestrian-friendly development and less car-dependent neighbourhoods.

The distance between production and (intermediate and final) demand determines the size of trade, and in turn, the demand for transport. As globalisation affects the volume of consumption, production and the place of production, it has great impact on the volume of transport.

#### **5. HIGHER EDUCATION IN PROMOTING THE EFFICIENT TRANSPORT & LOGISTICS NETWORKS**

However, the relationship between investment in knowledge and performance is complex and non-linear. What factors can explain the differences in innovative performance across countries with rather similar levels of knowledge investment? An important source of diversity between industrialised

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<sup>11</sup> D.A. Hensher & Brewer, A.M., **Transport. An economics and management perspective**. Oxford Univ. Press. p.2. 2004

economies relates to the respective roles of the main actors (i.e. firms, universities, and government and other public research institutions) in the process of knowledge production, diffusion and utilisation, as well as to the forms, quality, and intensity of their interactions. These actors are influenced by a variety of factors that exhibit some degree of country specificity: industry structure, the education and training system, the human resources and labour market, the financial system, etc. The World Bank calls this “Education for the Knowledge Economy” (EKE) and describes the topic as building “...the highly skilled and flexible human capital needed to compete effectively in today’s dynamic global markets” so that this power becomes “a major factor in development and is critical to a nation’s comparative advantage” and which comprises science, technology and innovation and information and communications technology.

Returning once more to the EU policies on this sphere, an important point is the so-called Bologna Process. This process refers to the signing of 29 European ministers of a Declaration (at the University of Bologna), the **Bologna Declaration** which aimed to undertake a European Higher Education Area. Bologna reforms are refocusing on higher education institutions, now that the legislative framework is largely in place. Universities must accept their responsibility to drive forward and urge governments to accept that the process needs time, and financial and human resources, to ensure long-term sustainability.

In short, as the world enters the 21st century, the quality of education continues to be a major factor in a nation’s ability to succeed and excel. In the 1950s and 1960s, education endeavours in transportation were focused at the college level, mainly through engineering programs. Development in the field now comes about because of continuing demands and commitments at several levels. First and foremost, within the educational establishment, formal academic programs have moved beyond traditional lines (e.g., engineering and science). As a result, transportation education programs are a formal area of study as well as an adjunct to or support for other established academic disciplines.

*“As the transportation education system grows, the focus is changing in several ways. From an academic standpoint, additional policy areas—as opposed to technical areas— become apparent. For example, students and professors broaden their scope to examine communication between public and private interests, strategic management of human and capital resources, environmental impacts, and most recently, the impacts of computerization and technology. The paradigm in transportation policy is shifting away from “bigger is better” to the more efficient management of existing infrastructure systems. The shift is being accomplished through the use of enhanced management systems and intelligent transportation systems.*

*At the same time, there is a growing realization that transportation education needs to broaden its focus beyond academic offerings. To interest future leaders (including traditionally underrepresented populations) in transportation careers, elementary and secondary curricula are being developed and revised.”<sup>12</sup>*

Here, one of the major factors to affect the context, philosophy and the pathway of the transportation education is the very fact of globalisation movement.

## 6. WHAT SHOULD BE IN THE AGENDA FOR THE FUTURE?

Today, transportation issues became more complex and more dependent on the developments in other sectors of the economy than in the past. Transportation issues were part of the academic agenda but did not have their own framework. It is no longer sufficient to have a technical background and it is and will continue to be a multidisciplinary and lifelong endeavour. In the 21st century, four areas will have a crucial effect on future innovation:

- globalization,
- technology,
- changing demographics and
- curriculum development.

Furthermore, we need to review our educational systems in terms of

- (a) the actors in education systems

<sup>12</sup> P.A. MANNING, **Transportation Education**. <http://onlinepubs.trb.org/onlinepubs/millennium/00125.pdf>

(b) the identification of the policy issues to which these systems are designed and implemented.

As the uncertainty for the future of the global economy draws points of interest on behalf of the policy-makers as well as the actors of the transport industry and curriculum developers, there are efforts to deal with these elements of blur. Ubbels, Rodenburg and Nijkamp for instance develop a scenario analysis to tackle this problem.<sup>13</sup> For them “*One way to deal with the (uncertain) impacts of globalisation is to construct several scenarios. The construction of these future images can be a useful tool for exploring the uncertain future. In the context of GITAGE,<sup>14</sup> the globalisation issues are identified in four scenarios. These address in various ways the process of globalisation, its effects on the various regions, political cooperation between regions, the pace of technological progress (see Nederveen et al., 1999), changing consumption patterns, and developments in the transport sector.*”<sup>15</sup>

In order to be competitive in the globalising knowledge economy, the developing countries need to invest in their innovation systems at the national and level, perhaps much more so than their developed counterparts. As the globally competitive countries are turning their production towards value-added segments and knowledge-intensive products and services, there is greater dependency on access to new technologies, knowledge and skills. And, with the parallel processes of globalisation and localisation, the local availability of knowledge and skills is becoming increasingly important.

In the design and development of educational models the very fact of the vitally important interactive working of transport and logistics networks should not be underestimated. This interaction is too costly to be ignored. Any educational programme should take into account the interactive format of freight transport and logistics networks. This brings us to the perspective of intermodal education. Intermodalism, in its simplest notion, involves the transport of both people and goods.

Depending on the findings of a TRB Conference Workshop<sup>16</sup>, we have to draw serious lessons from the fact that “*Many transportation professionals are not graduates of university transportation programs*”. This is an important point for the future of a safe and reliable planning of transport and logistics networks. R. D. Krebs point out that “

- *New applications for transportation and intermodalism do not come from a textbook; they come from real-life experiences - therefore, we need to educate the educator;*
- *Private companies need to support transportation education by providing financial support, contributing teachers, and participating in courses; and*
- *More research is needed on intermodalism, and these research results need to be incorporated into education and training.”<sup>17</sup>*

These facts urge us to suggest / propose that

- (1) A new and well-worked study has to be planned to work out the feasibility and comparable standards of available / present “university transportation and logistics programmes” covering a well-defined area for search.
- (2) The involvement and participation of a large spectrum of higher education institutions must be secured as well as public and private sector cooperation.
- (3) Be it either a “Conference” or a “Symposium”, a groundwork has to be carried out as a preliminary to search the existing transportation and / or logistics or transportation & logistics programmes in terms of intermodalism, interdisciplinary aspects, course contents, faculty involvement and programmatic inadequacies to see the inventory of the area.
- (4) The collaboration of an international parental organisation should be sought. This is important to safeguard the quality and competence of the work to be done.

<sup>13</sup> B. Ubbels & C. Rodenburg & P. Nijkamp, **A Multi-layer Scenario Analysis for Sustainable International Transport**. Tinbergen Institute Discussion Paper. TI 2000-102/3

<sup>14</sup> GITAGE, Globalisation, International Transport and the Global Environment

<sup>15</sup> ibid

<sup>16</sup> “Intermodal Transportation Education and Training, **TRB Conference Proceedings** # 17, 1998.

<sup>17</sup> R.D. Krebs, Intermodal transportation education and training, Keynote address. **TRB Conference Proceedings** # 17,

# THE ROLE OF EDUCATION AND TRAINING IN THE SUPPLY CHAIN SECTOR

*David Maunder<sup>1</sup>*

## **Abstract**

*The Chartered Institute of Transport [CILT] was founded in 1919 after the First World War where the logistics problems were magnified. The logistics and transport problems of the war and new modes of transport such as shipping and rail made it obvious that transport as a new subject needed to be studied, learned and developed if resources were to be used efficiently and effectively. In 1926 CIT was granted a Royal Charter to promote, encourage and coordinate the study and advancement of the science and art of transport in all its branches. In July 2001 the CILT became the Chartered Institute of Logistics and Transport [CILT]. There are currently over 30 sections and branches worldwide with over 30,000 members. From the beginning, the CILT's role has been education in the broadest sense: to spread knowledge and to be a source of authoritative views for communication to governments, industry and the community. The paper will explain the aims and objectives of CILT, its membership grades and describe its education courses which are aimed at different levels of the transport/logistics sector. The courses are designed to promote the highest standards of professional expertise and practice of those already working in the sphere of logistics and transport and lead to membership or chartered membership of the institution. The CILT holds charitable status.*

*Keywords: CILT, education, institute, logistics, NPO, supply chain management, transport*

## **1. INTRODUCTION**

The Chartered Institute of Transport [CILT] was founded in 1919. During the First World War, both motorized transport and aviation had become a reliable means of movement of both men and freight. There were thus two new modes of transport to be added to those of shipping and rail. The logistical problems of pursuing a war combined with the establishment of the new modes made it obvious that transport as a subject needed to be studied, learned and developed, if resources were to be used as efficiently and effectively as possible.

On November 26<sup>th</sup>, 1926 the Chartered Institute of Transport was granted a Royal Charter

*[a] to promote encourage and coordinate the study and advancement of the science and art of transport in all its branches, to initiate, foster and maintain investigation and research into the best means and methods of and appliances for transport, transit and locomotion and the problems that are involved and their most satisfactory solution, to extend, increase and disseminate knowledge and exchange information and ideas in regard to all questions connected therewith and to assist and further in all practicable ways the development and improvement of transport, transit and locomotion in the best interest of the community.*

*[b] to hold meetings of the Institute for reading and discussing communications bearing upon traffic and transport.*

*[c] to provide for the delivery of lectures, the holding of classes and examinations the awarding of certificates, medal, scholarships and diplomas in connection with traffic and transport*

*[d] to hold or promote exhibitions of appliances apparatus or systems of transport*

*[e] to form a library.*

On July 18<sup>th</sup> 2001 the Institute of Logistics amalgamated with the Chartered Institute of Transport and the Institute was renamed the Chartered Institute of Logistics and Transport [CILT].

From the beginning, the role of the CIT and latterly CILT has been education in the broadest sense: to spread knowledge and to be a source of authoritative views for communication to governments, industry and the community.

## **2. AIMS AND OBJECTIVES**

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The efficient movement of people and goods is vital to the quality of life enjoyed by society and the effective functioning of trade, the economy and essential services. Thus, it is desirable that all those involved in the planning, operation and management of logistics and transport should be well qualified for their work. This also applies to those engaged in allied activities, such as logistics and transport education, consultancy and research. They all make a crucial contribution to the effectiveness of the entire transport sector.

Throughout its history the CILT has constantly strived to achieve three objectives:

- To ensure an adequate supply of qualified personnel through an internationally recognized education and training programme/system
- To keep qualified individuals up to date throughout their professional career
- To play an active and influential role in shaping logistics and transport policies for the future development of the sector

In seeking to achieve its three objectives, the CILT aims can be summarized as follows:

- To promote the study of the science and art of logistics and transport
- To provide an educational programme with assessment and examinations leading to professional qualifications and membership grade within CILT
- To encourage members' active participation in continuing professional development
- To cooperate with the educational sector and fellow professional institutions with the objective of raising standards
- To foster investigation and research into the development and improvement of logistics and transport by every practical means
- To initiate regular meetings and the exchange of ideas through the medium of conferences, workshops, seminars, discussion groups, lectures, visits and other professional activities.

### **3. INTERNATIONAL ORGANISATION**

The CILT has always been an international organization, indeed over one third of the worldwide 30,000 membership are based outside of the UK. From Africa to Asia, Canada to Australia, Ireland to Hong Kong membership is growing. In recognition of the ever growing importance of its international status and activities, the CILT revised its executive structure in 1990. One of the resulting benefits is greater autonomy for and recognition of the larger local membership. There are now ten National Councils: in Australia, Hong Kong, India, Ireland, Malaysia, New Zealand, North America, Pakistan, Singapore and the UK. All administrative matters in these countries are handled locally, enabling a fast efficient and effective service to be provided for members.

In addition to National Councils there are Independent Sections and Branches in at least 20 other countries in Africa and SE Asia. In these countries some administrative functions are handled locally but many are handled by CILT International. All National Councils, Sections and Branches belong to CILT International which is the 'umbrella' organization for CILT worldwide and holds the Royal Charter- all members pay a small annual membership fee to CILT International.

There is close liaison between the local CILT organization and Ministry's of Education and Transport, universities and colleges training providers and major employers and employer associations. In this way, local needs where appropriate are sure of being recognized and incorporated into examination arrangements.

### **4. MEMBERSHIP GRADES OF CILT**

There are four membership grades namely:

- Student/Affiliate
- Member
- Chartered Member
- Chartered Fellow

All members are actively encouraged to progress through the different grades via experience of the logistics and transport industry, educational qualifications and continuing professional development [CPD]. By becoming a member of CILT members gain a lifelong professional anchor, a unique source of support,

knowledge and networking and an international membership qualification of a professional institute recognized throughout the world.

### **Student/Affiliate membership**

A student, already working in the logistics and transport sector can join as an affiliate member with the intention of studying and taking CILT qualifications at either Certificate or Diploma level. Otherwise anyone already working in the sector can join at this level but who do not aspire or qualify for higher membership grades.

### **Member**

The grade of Member is open to those who have relevant qualifications such as at CILT Certificate or Diploma level and have at least 3 years experience within the logistics and transport sector. A Member of CILT can use the post nominals MILT after his/her name.

### **Chartered Member**

Chartered membership is open to those who have successfully passed the CILT Advanced Diploma course [or exempting equivalent qualifications] and have at least 5 years relevant experience in the logistics/transport sector including 3 years at senior level. In addition, Chartered Membership can be applied for via the “*professional route*” where a candidate who lacks educational or professional qualifications provides a complete CV identifying his/her experience to date within the sector including where applicable evidence of papers submitted at conferences and seminars and presents a paper at a local CILT Section. Chartered Members can use the post nominals CMILT after their names and this is the grade that most will aspire to during their career.

### **Chartered Fellow**

This is the highest grade of membership. Fellowship is reserved for those who hold positions of high responsibility within the logistics and transport sector. Fellowship [FCILT] of the CILT is open to Chartered Members who have a minimum of at least 7 years senior management experience. In exceptional circumstances Fellowship grade is granted to individuals who have attained a position[s] of eminence in logistics and transport.

## **5. EDUCATION AND TRAINING**

The education and training processes of the CILT are independent, integrated and designed to promote the highest standards of professional expertise and practice of those working in the logistics and transport sector. The Institute now offers a three-tier professional qualification structure which deals with all major aspects of logistics and transport, following the prevailing industry best practices. The three-tier structure includes:

- The **International Certificate in Logistics and Transport** which is designed for first line supervisors and managers already working in the field of logistics and transport. Those who are successful in the Certificate course meet the knowledge and standards for membership [MILT] subject to a minimum of 3 years’ experience in the logistics and transport sector.
- The **International Diploma in Logistics and Transport** which is a higher level qualification aimed at those already working in the industry/sector at a middle management level. Those who are successful at the Diploma level course meet the knowledge standards for membership [MILT] subject to a minimum of 3 years experience in the logistics and transport sector.
- The **International Advanced Diploma in Logistics and Transport** which is an advanced course aimed at developing strategic decision making skills in logistics and transport for aspiring senior managers. Those who are successful in the Advanced Diploma course meet the knowledge standards for Chartered membership [CMILT] subject to a minimum of 5 years experience at a senior level in the logistics and transport sector.

A number of universities and colleges offer degree and diploma courses in logistics and transport and many of these are recognized by the CILT as satisfying all, or part, of the educational requirements either for Membership [MILT] or Chartered membership [CMILT]. Some of these institutions also offer courses for the CILT examinations. At most of these institutions, there are Chartered Members on the academic staff who in addition to their experience in education and research have invaluable practical experience in the logistics and transport sector. Some National Councils are able to offer their own courses leading to CILT qualifications.

These courses may have local variations in content to meet local market requirements but all are based on key knowledge areas for membership in line with CILT International courses and qualifications.

## 6. THE INTERNATIONAL CERTIFICATE IN LOGISTICS AND TRANSPORT

This qualification is designed for front line supervisors and managers working in the logistics and transport industry. It is intended to increase knowledge, skills and confidence as part of the managerial role for a junior manager within the industry.

The course consists of 7 units or modules of which 3 are mandatory for all students to study. Students then have a choice of one unit from a selection of 4. Either at the end of each unit or when all 4 units have been studied students take examinations with the pass mark set at 50%.

The 3 core subject units that all students have to take are the following:

- Managing the Logistics and Transport Environment
- Managing Resources
- Customer Service and Quality Management in Transport Operations

Optional Units comprise the following:

- Warehousing and Store Operations
- Freight Operations
- Fleet Management
- Passenger Transport

As an example of the extent of the course content the topics included for the three core subjects that have to be studied by all students is shown below:

*Managing Resources* comprises 3 topics namely: People, finance and technology.

*Managing the Logistics and Transport Environment* comprises: Internal structures and processes, external factors, stakeholder interests, marketing and commercial needs, legal and environmental issues.

*Customer Services and Quality Management* comprises topics such as: Customer service and competition, customer service culture, developing, maintaining and improving service quality, setting and monitoring service standards, analysing quality problems and service failures, TQM, MIS, benchmarking, legal requirements, admin systems and communications.

The elective modules are equally extensive in terms of topics covered. The syllabus is set out into units which are then broken down into topics of knowledge and competencies. Key learning points and coverage are also provided for each unit.

Each unit/module takes approximately 60 hours of study so the entire course takes 250 hours of which 100 hours will be taught in the classroom.

A Training Provider needs to be accredited by CILT International to run the course following a recommendation from the local CILT Section. Accreditation depends on meeting a set of criteria including facilities and staff experience to teach the courses.

Upon accreditation the teaching materials are provided on a CD for the local training provider who then needs to localize/ customize the material to the local environment. The teaching material is both student and teacher friendly and is ideal for self tuition.

So the course is taught locally using internationally provided teaching materials and examinations are set locally and marked locally but moderated by CILT International to ensure quality control and standards are maintained at similar levels throughout the CILT international community.

The course meets the knowledge standards required for Membership of CILT subject to a minimum of 3 years experience in the industry.

## 7. THE INTERNATIONAL DIPLOMA IN LOGISTICS AND TRANSPORT

The **CILT International Diploma** builds on knowledge gained from studying the Certificate course or from the working environment itself. It is set at a higher level than the Certificate and will consequently take longer – possibly 500 hours of study of which 200 will be classroom based and the rest in self tuition. The qualification is basically for those already in middle management posts who wish to develop a strategic view of logistics and transport operations and be capable of reviewing and modifying operational activities.



It is a modular course comprising 6 units **all** of which have to be studied. The units comprise:

- Managing Transport and Logistics Operations
- Resource Management
- Transport Economics and Finance
- Supply Chain and Logistics
- Inventory Management
- Passenger Transport

For each unit detailed Power Point Presentations are provided as teaching material which is user friendly for lecturers and easily understandable for students. As with the Certificate course however, lecturers need to localise the presentations by incorporating additional material to cover the local economy, transport and logistics sector and environment. Topics for three of the six units are shown below as an example of the entire course.

The *Transport Economics and Finance* unit comprises topics such as: Transport supply and demand, externalities, economics and finance, costs and budgetary measures, decision making and evaluation and statistical research methods.

The unit *Managing Transport and Logistics Operations* includes topics such as: Organisational structure and relationships, transport characteristics, logistics and supply chain, customer service, information technology, the business environment and planning, controlling and decision making.

*Passenger Transport* comprises: Movement of people, origins, destinations and routes, handling of passengers, modes of passenger transport and services.

As with the Certificate course training providers have to be accredited by CILT International to run the course but upon accreditation the teaching materials are provided. All six units are examinable with the examination papers and marked scripts moderated by CILT International to ensure quality control and standards. Depending on the candidates experience and knowledge students do not need to study the Certificate course before starting the Diploma. However, the course is set at a higher level and so candidates need to have a good basic knowledge of logistics and transport before commencing the course.

The course meets the knowledge standards required for Membership of CILT subject to a minimum of 3 years experience in the industry.

## 8. THE INTERNATIONAL ADVANCED DIPLOMA IN LOGISTICS AND TRANSPORT

This advanced course which is the equivalent of a degree is primarily aimed at developing strategic decision making skills in logistics and transport. Modern companies in their efforts to cope with an ever changing and challenging environment use two key processes to build and sustain their future. The first is strategic planning which enables top management to determine what business direction it wants to achieve. The second is logistics and transport planning which enables the company to proceed in a systematic way to identify and turn specific opportunities into revenue streams and profitability.

The course presents the conceptual idea of integration of logistics and transport planning into the strategic planning process.

Students who study for the Advanced Diploma are expected:

- a) To become familiar with certain elementary analytical concepts useful to analyse logistics and transportation environmental trends, customers, organization, finance, and cost dynamics.
- b) To develop an understanding of logistics and transportation strategic planning methods including strategic management and leadership, strategic environment, and organization level planning.
- c) To integrate and apply the concepts discussed into their daily workplace.
- d) To be aware of ethical issues, sustainability and minimizing the impact of the organization and its operations on the global environment
- e) To develop skills in research methodology and produce a work-based project.

Teaching material has not been developed at the present time though Standards or a Syllabus has been finalised. Therefore, a Training Provider who wishes to offer the course needs to create teaching material based on the Standards provided by CILT International. It is expected that students will study for at least a 2 year period before completing the course.

Four core Units comprise the course which **all** students have to study and they comprise:

- Strategic Management and Leadership
- Strategic Environment for Logistics and Transport
- Organisation Level Planning in Logistics and Transport
- Research Methodology which includes a work based research project.

The course content comprises the following:

*Strategic Management and Leadership* topics include: organisational culture, leadership, collaboration and ethical management.

*The Strategic Environment for Logistics and Transport* comprises: society and sustainability, government and politics, economics, finance and risk and contingency planning.

The topics included in *Organization Level Planning in Logistics and Transport* comprise: vision and strategy, transportation planning, delivering customer service, innovation and change, supply chain performance

*Research Methodology and Work-based Project* includes topics such as: nature of business and management research, research approaches, sampling and data and a work based project.

The first 3 units are examinable and moderated as for the Certificate and Diploma courses and the work based project is assessed locally but moderated by CILT International to maintain standards.

Those who are successful in the Advanced Diploma course meet the knowledge standards for Chartered membership [CMILT] subject to a minimum of five years experience at a senior level in the logistics and transport sector.

## 9. CONCLUSIONS

The Chartered Institute of Logistics and Transport is the leading professional body associated with the logistics and transport industry. With over 30,000 members in 30 countries worldwide CILT holds unparalleled professional recognition.

Established in 1919 and receiving its Royal Charter in 1926, the Institute has a traditional history but is constantly adapting to stay consistent and relevant to today's worldwide logistics and transport issues. Close links are still retained today with the British Royal household as they have throughout CILT's history. In 1922 HRH the Prince of Wales was made the Honorary President whereas currently HRH the Princess Royal is the CILTUK Patron and Her Royal Highness Queen Elizabeth is the CILT International Patron.

The principal objective of the Institute is '*to promote and encourage the art and science of logistics and transport*'. The Institute achieves this objective through both its membership and its educational qualifications.

Membership provides a professional identity and international recognition to those already employed in the logistics and transport sector. The Institute's professional qualifications educate not only those already in the sector but also those wishing to enter it.

The CILT holds charitable status and so resources are invested for the benefit of its members throughout the CILT worldwide community.

# **Chapter 4**

## Supply Chain Management



## MODELING REVERSE FLOWS IN A CLOSED –LOOP SUPPLY CHAIN NETWORK

Vildan ÖZKIR<sup>1</sup>, Önder ÖNDEMİR<sup>2</sup> and Hüseyin BAŞLIGİL<sup>3</sup>

**Abstract** — This paper seeks to describe features of establishing a closed-loop supply chain for the collection of End-of-Life Products. To address this issue, the problem is handled through reverse logistics and is modeled as a capacitated facility location problem. The main purpose of the study is to describe a general closed loop supply chain including customers, collection points, reverse centers, plants and recovery facilities. In this context, we propose a mixed integer nonlinear programming model for this problem in which product recovery processes can be viewed in three steps. First step is to determine the number and location of collection points where returned products from end-customers are collected. In the second step, these products are sorted and classified in order to properly recover these items in reverse centers (disassembly, de-manufacturing or refurbishing options). Ultimately in the third step, returned products are recovered as refurbished products in recovery facilities. We developed a numerical example to illustrate the usefulness of the proposed model and obtained the solution by using GAMS software.

**Keywords** — Closed Loop Supply Chain, Product Recovery Options, End of Life Product.

### INTRODUCTION

Supply chain management has emerged as one of the major areas for companies to gain a competitive edge. Managing supply chains effectively is a complex and challenging task, due to the current business trends of expanding product variety, short product life cycle, increasing outsourcing, globalization of businesses, and continuous advances in information technology [Lee, 2002].

A supply chain has traditionally been considered as a line, starting with the movement of goods from suppliers to manufacturers, and going ahead with wholesalers, retailers, and finally reaching to consumers through these distribution channels. Nowadays, this line is continuously getting closed, namely a circular chain occurs. Hence, complex industrial relationships prove the existence of material flows not only going downstream but also going upstream during the production, distribution, and consumptions stages.

Reverse logistics has been spreading worldwide, involving all layers of supply chains in most of the industry sectors. Take back obligations, environmental concerns and customer pressure forced reverse logistics to become a key component in modern supply chain.

The first known definition of reverse logistics was published by the Council of Logistics Management (CLM): ‘... the term often used to refer to the role of logistics in recycling, waste disposal, and management of hazardous materials; a broader perspective includes all activities relating to logistics carried out in source reduction, recycling, substitution, reuse of materials and disposal.’

Forward supply chain management covers all business functions and decisions related with the flow of goods starting from supplier to end customer while reverse supply chain management covers the opposite flow which oriented towards recovery processes starting with collection of returns from end customers. Forward supply chain associates with reverse supply chain by closing the material flow regarding environmental and economic concerns.

The attempts for management of forward and reverse flows of goods are being researched in the area of the closed loop supply chain management. Closed loop supply chain studies in the literature especially investigate the design and recovery concepts.

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This study aims to represent a model framework for designing the product recovery process in a closed loop supply chain. This framework represents a novel example for multi-level, multi-commodity and capacitated product recovery network in the whole CLSC. This paper is organized as follows. Section 2 reviews existing research and approaches for the design strategies of a supply chain. In section 3, we introduce a closed loop supply chain (CLSC) structure and material flows in it. In section 4, we identify the main formation of proposed CLSC model. In section 5, we present the results of research and, we conclude in section 6.

## **SUPPLY CHAIN DESIGN**

Supply chain design studies aims to establish an effective and efficient system for the flow of all materials in the supply chain regarding environmental concern. The success of supply chain depends on its design; the success of the chain design depends on how close the chain is. The closeness of the loop is measured by the amount of waste which influences environmental concern. So, it can be said that supply chain gets closer if and only if it generates less the waste. Hence waste disposal is another key factor for a successful chain.

The unique principle when designing a supply chain is related directly to cost minimization issue. Besides this, CLSC has additional design principles emanated from the requirement of sustainability. Krikke, Pappis, Tsoulfas ve Bloemhof-Ruward (2001) summarized the additional principles - matching network design with recovery options, enhancing quality and rate of return, enhancing design for recycling and etc.- that these principles generally serves as environmental principles. The more waste the chain generates, the more the chain have to dispose of. Consequently, the design of the CLSC has to aim reducing disposal costs, improving less waste generating designs and increasing the usage of more recyclable components.

Environmental issues are mostly related with recovery, reuse, remanufacture, and recycle operations. Studies regarding environmental concern mostly charged with exploring the best opportunity for closing the supply loop. On the other side, typically, supply chain design studies strive to find the best set of inventory, transportation, and production decisions. Therefore, the problems confronted during these studies are of higher complexity and have multi-dimensional characteristics.

Supply chain design is a complicated project which needs an extreme effort to balance the environmental parameter(s) and profit parameter(s). Environmental parameters are smart indicators of sensitive behaviors for minimizing environmental damage by reducing the impacts of wastes and respectively waste disposals that occur in the lifecycle of a product(s). Profit parameters are cost dependent indicators involving the costs generated from production, transportation, warehousing, etc., and revenues related with price and sales.

The success of supply chain is directly related with the perfection of its design. The perfection of the design can be revealed by measuring the performance of the design. Performance measurement process and key performance indicators are widely studied in the literature (Hill, 1993; Agarwal et al., 2006; Beamon, 1999; Gunasekaran, Patel and McGaughey 2004; Lai, Ngai and Cheng 2002; Kleijnen and Smits 2003).

## **CLOSED LOOP SUPPLY CHAINS (CLSC)**

Closed Loop Supply Chain (CLSC) practices, recoverable product environments, and the design of these products and materials, have become an increasingly important segment of the overall push in industry towards environmentally conscious manufacturing and logistics [Zhu, Sarkis and Lai, 2008].

CLSC management comprehends all business functions and hence decisions regarding the adaptation of business strategy, marketing, quality management, information systems, logistics and so on in view of closing material flows, thereby limiting emission and residual waste, but also providing customer service at low cost [Krikke et al., 2001]. Both the forward chain and the reverse chain are considered, since there is a strong interaction between the two of them.

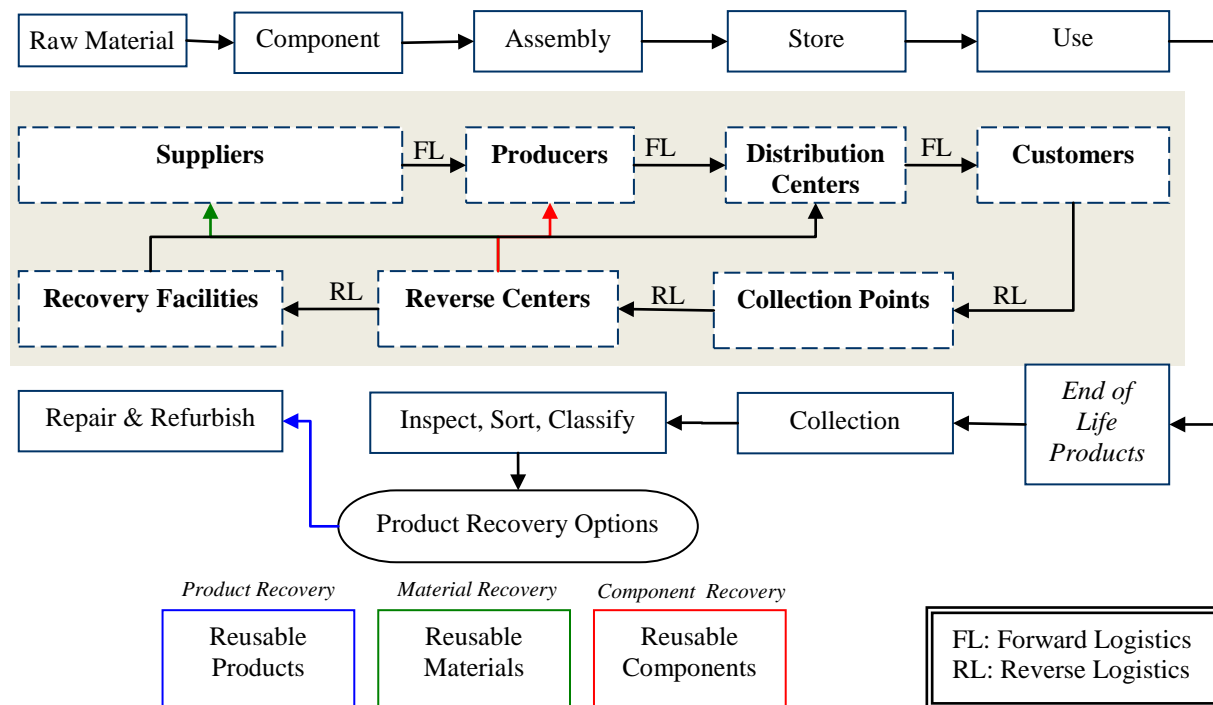


Figure 1: Closed Loop Supply Chain Flows

Forward supply chain includes all movement and storage of raw materials, work-in-process inventory, and finished goods from point-of-origin to point-of-consumption while reverse supply chain considers the reverse flow of any type of returns from point of consumption to the point of recovery process ends. Reverse supply chain investigates how to establish a physical reverse channel and information flow to support the strategy (including standardized processes and procedures for minimizing the causes of returns and facilitating the efficient physical flow of planned returns from customer to final disposition). Besides this, it also investigates how to design the best reverse logistics system and return disposition strategy that minimizes cost and liability, maximizes reverse velocity, profitability, asset value recovery, and customer loyalty. Tibben-Lembke and Rogers (2002) presented a unique study examining the similarities and differences between reverse and forward logistics.

CLSC refers to an integrated framework including both forward and reverse supply chain. But, it is essential to understand in what respects closed loop supply chain design will be affected from forward supply chain design and/or reverse supply chain design.

## CLOSED LOOP SUPPLY CHAIN MODEL

The main purpose of proposed model is to describe a general closed loop supply chain including customers, collection points, reverse centers, plants, distribution centers and recovery facilities. We formulate a multi-product, multi-echelon, multi- period and profit maximizing closed loop supply chain model covering activities from suppliers to recovery facilities. Thus, we present a mixed integer linear programming model regarding possible product recovery options in the context of closed loop supply chain.

The optimization model aims to determine the optimal locations for collection points, reverse centers, plants and recovery facilities while maximizing the profit. Proposed CLSC model can be summarized as follows:

$Profit = Total\ Sales\ Revenue - Total\ Fixed\ Cost - Total\ Setup\ Cost - Total\ Purchasing\ Cost - Total\ Transportation\ Cost - Total\ Processing\ Cost - Total\ Holding\ Cost - Total\ Penalty\ Cost.$

Total Sales Revenue can be calculated by summation of recovered product Sales, new Product Sales and Recovered Material Sales.

Total Fixed Cost can be calculated by summation of all fixed costs in collection centers, reverse centers, plants, recovery facilities, and distribution centers.

Total Setup Cost can be calculated by summation of all setup costs in collection centers, reverse centers, plants, recovery facilities, and distribution centers.

Total Purchasing Cost can be calculated by summation of procured components in plants and retrieving cost in collection centers.

Total Transportation Cost can be calculated by summation of all transport cost related with all closed loop supply chain echelons.

Total Processing Cost can be calculated by summation of total disassembly cost, total de-manufacturing cost, total disposal cost, total production cost, total sorting and classifying costs and total refurbishing costs.

Total Holding Cost occurs in reverse centers and distribution centers. Reverse centers handles products and components but distribution centers handles products in two forms: recovered products and new products.

Total Penalty Cost occurs on dissatisfied customer demand situations.

The proposed optimization model maximizes profit function subject to these constraints:

The optimization model for collection center location decision minimizes investment (fixed and running costs of facilities as well as transportation costs) subject to following constraints:

- (1) Goods collected from customers must go to an open (available) collection center,
- (2) All goods collected from a customer must go to exactly one collection center,
- (3) Minimum number of collection points (CP), reverse centers (RC), plants (P), distribution centers (DC) and recovery facilities (RF).
- (7) Capacity constraints.
- (5) Balance equations for material flows.
- (6) All parameters and variables are non-negative.

Quantity of any customer demand for each product type in a particular time period, unit sales prices, distance between arrival and destination nodes, unit transportation cost for products per unit distance and fixed costs, setup costs, unit processing costs are some of the important input parameters used in this model. The binary decision variables decide whether a facility is opened during a particular time-period and also ensure that a particular return goes to one open facility only.

The optimization model decides the number of each facility type and where these facilities are located while maximizing profit of the whole closed loop supply chain.

## NUMERICAL APPLICATION

In order to illustrate the application of the proposed model, we consider a multi-stage, multi-period, and multi-commodity supply chain design. The example is a medium size problem that given parameters are customer demands per period, unit sales price of products, component quantities and component types in a product type, unit processing costs, unit transportation costs and alternative location destinations. All the other input data are available upon request and all the instances are modeled with GAMS.

We can summarize the stages in the closed loop supply chain as follows: In every period;

- Customer demands occur in two forms:
  - Demand for New Products: Brand new products have higher prices with life long guarantee.
  - Demand for Recovered Products: Lower prices with limited life long guarantee.
- Customer returns occur for two reasons:
  - Retrieve Price: To improve the quality and the quantity of returns, company offers a financial incentive for each return. In this case, we assume the amount of incentive offered by the company is equal for every quality level and for every type of used product returns.
  - Environmental Sensitiveness or Environmental Legislations.

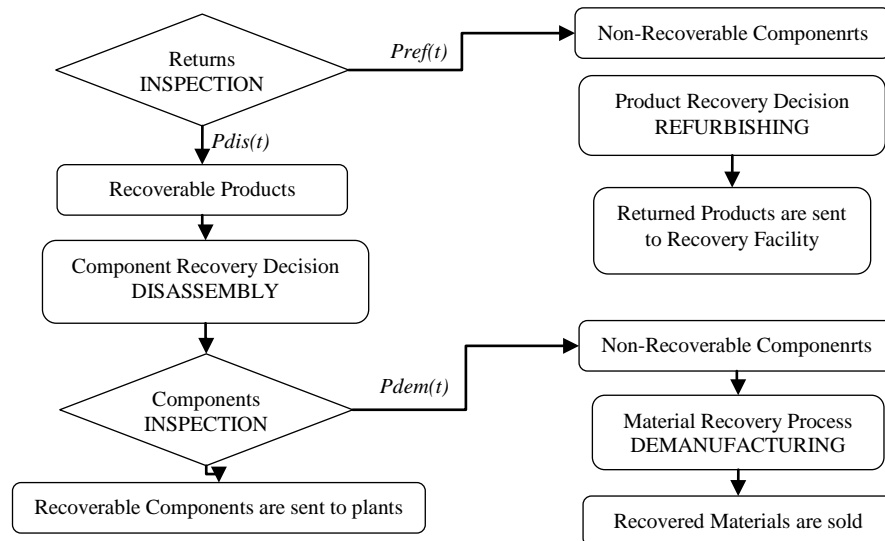


- Collection of Returns: Used product returns are collected from customers by collection points. The unique responsibility of collection points (CP) is to collect used products from customers



and to send them to reverse centers for inspection, sorting and deciding the best recovery option.

- **Reverse Center Operations:** Product returns are inspected in reverse centers. Inspected returns are sorted according to inspection results. Inspection results includes the decision of recovery option. The main purpose of reverse centers (RC) is to explore the best recovery option. In this case, we assume that reverse centers are able to disassemble (or demanufacture) a returned product. Product recovery decisions includes:
  - **Product Recovery Option:** Returned product requires only small repairing or refurbishing process. Each component of product corresponds to the requirement of the minimum life-time for related product design. In our case, to facilitate mathematical formulation, we defined  $Pref(t)$  as the ratio for product recovery option which is given for each period  $t$ .
  - **Component Recovery Option:** If any component of returned product does not work or does not correspond to the requirement of the minimum life-time, this returned product is disassembled to its components. If any component of a returned product works, this component can be used in the production of recovered product. In our case, we defined  $Pdis(t)$  as the ratio for component recovery option including disassembly process.
  - **Material Recovery Option:** If any component of a returned product does not work or does not correspond to the requirement of the minimum life-time, this component can only be recovered by demanufacturing process. Demanufacturing process includes transforming products (or components) to their materials that they are formed. We defined  $Pdem(t)$  as the ratio for material recovery option after disassembly process. We show the decision procedure in figure .... for product recovery process.



**Figure 2: Product Recovery Process**

- **Recovery Facility Operations:** Recovery facilities are responsible with repairing and refurbishing operations. Repaired or refurbished products are sent to distribution centers after packaging process.
- **Distribution Center Operations:** Distribution centers serves customer in two types. In our example, system works with two types of products and these two types of products may be in two forms: recovered products or new products. The supply channel of recovered products is recovery facilities while the supply channel of new products is plants.

In our example, closed loop supply chain occurs four types of candidate location for any type of facility (CP, RC, RF, P, DC) and five major customer locations. Costs for setting up a facility and costs for fixed processing are given. Hence, the model decides where to locate each type of facility in each period. We restricted model by a constraint which guaranties an open facility remains open for the rest of periods. The facility locations and the quantities are decided by the model regarding total

transport cost, total setup cost and total fixed cost. Maximum profit is calculated as 189.800 USD and setup decisions are summarized in Table 1.

Setup Decisions					
	Plants	DCs	CPs	RCs	RFs
Final Locations	P3	D2, D3	J1,J2,J3,J4	R1	F2

**Table 1: Set up decisions**

## SUMMARY AND CONCLUSION

Environmental legislations and concerns leave no choice to companies but to improve their responsibility on product life time. They are responsible with exploring the best opportunities for consuming fewer natural resources by evaluating more recovery options for end of use and/or end of life products.

Closed-loop supply chains open up a new and interesting set of issues to be addressed by industry. They also offer opportunities for meaningful academic research that takes into consideration the interdisciplinary nature of the problems and the need to develop frameworks and models based on an integrated-business-process perspective (Guide, Harrison and Van Wassenhove, 2003).

In this study, we propose a framework for CLSC model for strategic decisions related to forward supply chain and reverse supply chain operations from the view of product recovery. The developed model allows the comprehensive description and analysis of the system operations taking into account the “green image” for supply chain design. Especially, proposed framework includes a detailed product recovery process and the goal of the proposed model is maximization of profit function.

The world is changing very rapidly, and companies, in cooperation with academics, must quickly develop supply chains that can handle coordinated forward and reverse flows of materials. They must develop methods of showing managers the benefits to be obtained by developing reverse supply chains. If managers cannot quantify the potential financial (and nonfinancial) benefits, they are unlikely to consider return flows as anything other than a nuisance, for which they must minimize losses (Guide, Harrison and Van Wassenhove, 2003).

Overall, the model developed here can help practitioners to design better CLSCs having the ability to respond quickly to consumers need and determine the right policies to manage the operations efficiently. An organization can economically benefit from savings by effectively managing a supply chain. Thus, we proposed a MILP model for a multi-stage closed loop supply chain system which provides insights in formulating the problem.

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# STRATEGIC ANALYSIS OF GREEN SUPPLY CHAIN MANAGEMENT PRACTICES IN TURKISH AUTOMOTIVE INDUSTRY

Gülçin BÜYÜKÖZKAN<sup>1</sup> and Alişan ÇAPAN<sup>2</sup>

**Abstract** — Environmentally responsible manufacturing, green supply chain management (GSCM), and related principles have become an important strategy for companies to achieve profit and gain market share by lowering their environmental impacts and increasing their efficiency. This paper examines the main components and elements of GSCM and how they serve as a foundation for an evaluation framework in Turkish Automotive Industry. The identified components are integrated into a strategic assessment and evaluation tool using analytical network process (ANP). The dynamic characteristics and complexity of the GSCM analysis environment make the ANP technique a suitable tool for this work. The supplied case studies provide additional insights for research and practical applications.

**Keywords** — Analytic network process, green supply chain management, strategic decision making, Turkish automotive industry.

## INTRODUCTION

As competition has intensified and globalized over the last decade, supply chain management has received greater attention by manufacturing organizations. Firms increasingly rely on their supply network to handle more complex technologies and higher customer expectations. Among these expectations, increasing attention is devoted to suppliers' social responsibility with a particular focus on fair and legal use of natural resources. Green supply chain management (GSCM) has emerged as an important new broad-based innovation that helps organizations develop 'win-win' strategies that seek to achieve profit and market share objectives by lowering their environmental risks and impacts, while increasing their ecological efficiency [1]. Environmental impacts occur at all stages of a product's life cycle, from resource extraction, to manufacturing, use and reuse, final recycling, or disposal. Interdisciplinary research has integrated the efforts of management, engineering, physical and social sciences to investigate the issues relevant to this topic. Similarly, multifunctional groups within organizations and external stakeholders have a role in decisions related to organizations and the natural environment. When organizational environmental decisions are to be made they will necessarily be strategic and usually more complex for this reason. These decisions will have internal and external implications for the management of an organization. Green supply chain decisions are one of the latest issues facing organizations with strong internal and external linkages [2]. One approach to model the dynamic nature of business and its relationship to the natural environment into a decision framework is a technique that is capable of considering the multidimensional qualitative and strategic characteristics. This paper is one that addresses this issue. Our aim is to identify and structure the primary strategic and operational elements for a framework that will aid managers in evaluating green supply chain alternatives.

The structure that is developed in this paper is a network hierarchy that can be used to evaluate the alternatives. The technique for analyzing the decision is based on the analytical network process (ANP) approach first introduced by Saaty [3]. The dynamic characteristics and complexity of our decision environment, which is true for most strategic decisions, makes the ANP technique a suitable tool.

Ford Otosan, Hyundai Assan and Toyota are selected as case companies in this study for the evaluation of GSCM alternatives. The supplied case studies provide additional insights for research and practical applications.

The organization of the paper is then as follows. The paper begins with a presentation of the suggested approach. Then, we attempt to structure various main components of the GSCM into an evaluation framework. After a brief review of ANP, the next section includes the illustration of the methodology through the cases of three automotive companies. As a conclusion, the paper gives some concluding remarks.

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## AN EVALUATION FRAMEWORK FOR GSCM

GSCM is gaining increasing interest among researchers and practitioners of operations and supply chain management. Three drivers (economic, regulatory and consumer pressure) drive GSCM worldwide. It integrates sound environmental management choices with the decision-making process for the conversion of resources into usable products. GSCM has its roots in ‘environmental management orientation of supply chains’. It has emerged as an effective management tool and philosophy for proactive and leading manufacturing organizations. The scope of GSCM practices implementation ranges from green purchasing to integrated life-cycle management supply chains flowing from supplier, through to manufacturer, customer, and closing the loop with reverse logistics. A number of definitions of GSCM exist [4], [5]. The research in GSCM addresses a variety of issues ranging from organizational research and practice in GSCM [6-9] to prescriptive models for evaluation of GSCM practices and technology [2], [9-11]. This study proposed an analytic approach based on the ANP methodology to assist in GSCM strategic decisions. The following two main phases are realized.

### **GSCM Conceptualization Phase:**

- Determine and classify the factors that influence the success of GSCM with a literature review.
- Through discussion with industrial experts, if there exists, add different analysis dimensions or views in evaluation framework.
- Determine possible interactions and/or relationships among factors and criteria; and develop an evaluation model.

### **GSCM Analysis Phase:**

- Calculate the relative importance weights of the factors by means of pair wise comparisons supplied by industrial experts of the case company.
- Form a supermatrix (i.e. a two dimensional matrix composed from the relative-importance-weight vectors) and normalize it so that the numbers in every column sum up to one.
- Calculate the converged (“stable”) weights from the normalized supermatrix.
- Calculate the final score of each green supply chain alternative for the case companies.

## GSCM CONCEPTUALIZATION PHASE

A detailed literature search with the concepts related to “green supply chain” is realized. We can find some concepts and elements which can be served as the foundation for a decision framework for prioritizing or selecting systems by the organization that will aid in managing green supply chains [2], [4], [5], [9], [12-19]. They are summarized as follows.

- New Product Development Phases : New product development (NPD) is the complete process of bringing a new product or service to market. Green new product development (GNPD) is defined here as product development into which environmental issues are explicitly integrated in order to create one of the least environmentally harmful products a firm has recently produced. The main difference between GNPD and traditional NPD is that GNPD is more focused on products post-use, and particular design for the ‘Five R’s’ of repair, reconditioning, reuse, recycling, and remanufacture [20]. The NPD process consists of several phases. Following of Rosenthal [21], this study considered four steps NPD process model which consists of ideas generation and conceptual design, definition and specification, prototype and development, and commercialization.

- Design for Environment : Design for Environment (DFE) encompasses the process by which environmental issues are incorporated into the product realization process. DFE might be the most preferential way to improve green supply chain because changes in the design can cost-effectively leverage environmental effects both upstream and downstream. Valentincic [22] characterized DFE by a simultaneous design of a product and its manufacturing process in order to achieve the best outcome and consequently optimize the overall costs. Major elements of the DFE dimension include design for manufacturing, design for assembly and design for packaging.

- Green Logistics Dimension: A more tactical set of organizational elements that will influence how the supply chain is to be managed, either internally or externally, can be described by green logistics dimension of an organization. Major elements of the green logistics dimension typically include procurement, production, distribution, reverse logistics and packaging [2], [14], [23-24]. From procurement to reverse logistics these

steps encompass whole the life cycle of the products. Although packaging is not viewed as a lifecycle element, it is also affect GSCM.

- ***Green Organizational Activities Dimension :*** The major five green organization activities dimensions are reduce, reuse, remanufacture, recycle and disposal [2], [25]. Extended Producer Responsibility (EPR) requires firms for developing these activities. The responsibility of the environmental impact of products throughout their entire life cycle embraces also the end of life effects.
- ***Manufacturing Priorities :*** Manufacturing priorities can be defined as a set of coordinated objectives and action programs applied to a firm's manufacturing function and aimed at securing medium and long term, sustainable advantage over that firm's competitors. In this study, manufacturing priorities are identified as quality, delivery, efficiency, flexibility and customer service.
- ***Green Supply Chain Alternatives :*** In this study, we focus on three supply chain alternatives according to the framework created for the purpose of evaluation of the GSCM. In the framework, alternative 1 (ALT1) is identified as JIT (Just in Time), alternative 2 (ALT2) as environmental focused supply chain management and alternative 3 (ALT3) as current SCM system of the case company. It is obvious that every SCM system has different advantages and disadvantages. In consequence they have different environmental effects.

The next step of the study is to justify the proposed structure and derive the interactions and/or relationships in the identified components. This step is realized through review of literature on GSCM, through discussion with industrial experts and our expertise. Finally, the final shape of the conceptualization phase and the relevant components are structured as given in Figure 1.

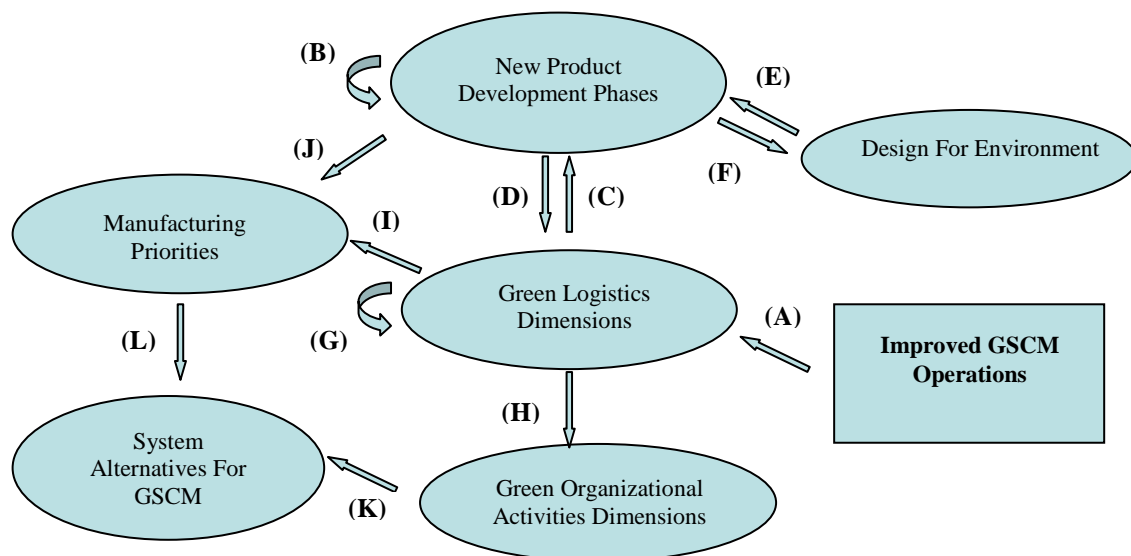


FIGURE 1

Graphical representation of dimensions and relationships of decision framework for evaluating GSCM.

The GSCM system is evaluated on five different dimensions (levels or clusters); the Green Logistics, the Green Organizational Activities, the New Product Development Phases, the Design For Environment and the Manufacturing Priorities. In this study, the interdependence or feedback type relationship occurs between both the green logistics and the new product development dimensions and the new product development and the design for environment as represented by two reverse arrows among those levels. The other arrows in the model indicate a one-way relationship. In addition, the interdependency relationships of green logistics elements and the new product development phases are shown by looped arcs in Figure 1. The capital letters from A to L in parentheses in Figure 1 represent the weight matrices used in the supermatrix construction which is described in details in following section. In the framework, the current supply chain systems of the case companies are compared to two other alternatives (ALT1 and ALT2). The end result or the model will indicate which system best meets the needs of the decision maker based on interaction between five different dimensions.

## GSCM ANALYSIS PHASE

### Analytic Network Process

Selection of a suitable methodology that can decode the high-level relationship model presented in Figure 1 in order to evaluate possible GSCM alternatives is a critical issue. This methodology should be able to use quantitative, qualitative, tangible, and intangible factors pertaining to the decision of whether and which alternative should be evaluated. With this trend, ANP is capable of taking the multiple dimensions of information into the analysis. ANP is a general form of the analytical hierarchy process (AHP) first introduced by Saaty [3]. While the AHP employs a unidirectional hierarchical relationship among decision levels, the ANP enables interrelationships among the decision levels and attributes in a more general form. The ANP uses ratio scale measurements based on pair wise comparisons; however, it does not impose a strict hierarchical structure as in AHP, and models a decision problem using a systems-with-feedback approach. The ANP refers then to the systems of which a level may both dominate and be dominated, directly or indirectly, by other decision attributes and levels. The ANP approach is capable of handling interdependence among elements by obtaining the composite weights through the development of a “supermatrix”. Saaty [3] explains the supermatrix concept similar to the Markov chain process. The supermatrix development is defined in the next sub-section. Although the number of ANP related works has increased in the recent years, there are only four studies realized by Sarkis to our knowledge that are used for environmentally related problems. After presenting a model for evaluating environmentally conscious business practices [12], Sarkis [26] proposed a methodological framework for evaluating environmentally conscious manufacturing programs. This second research integrated the ANP and data envelopment analysis. More recently, Meade and Sarkis [27] used ANP to evaluate and select third party reverse logistics providers while Sarkis [2] used ANP in a decision framework for GSCM.

### Application of the Evaluation Framework in the Case Companies

In the strategic analysis of the GSCM framework, Hyundai Assan ([www.hyundai.com.tr](http://www.hyundai.com.tr)), Ford-Otosan ([www.ford.com.tr](http://www.ford.com.tr)) and Toyota ([www.toyotatr.com](http://www.toyotatr.com)) are analyzed. These firms are selected because they are world wide firms and they have severe applications on GSCM. Deniz Külahlıoğlu (Hyundai-Assan), Vedat Okyar (Ford-Otosan), Serdar Aydın (Ford-Otosan) and Mustafa Diker (Toyota) offered guidance for the application of the GSCM framework.

- *Pair wise comparisons and the calculation of relative importance weights:* Eliciting preferences of various components and attributes will require a series of pair wise comparisons where the decision maker will compare two components at a time with respect to an upper level 'control' criterion. In ANP, like AHP, pair wise comparisons of the elements in each level are conducted with respect to their relative importance towards their control criterion [3]. Saaty [28] has suggested a scale of 1 to 9 when comparing the two components, with a score of 1 representing indifference between the two components and 9 being overwhelming dominance of the component under consideration (row component) over the comparison component (column component). If a component has a weaker impact on the control criterion, the range of scores will be from 1 to 1/9, where 1 represents indifference and 1/9 an overwhelming dominance by a column element over the row element. When scoring is conducted for a pair, a reciprocal value is automatically assigned to the reverse comparison within the matrix. That is, if  $a_{ij}$  is a matrix value assigned to the relationship of component  $i$  to component  $j$ , then  $a_{ji}$  is equal to  $1/a_{ij}$  (or  $a_{ij} * a_{ji} = 1$ ). The weightings have been obtained from our industrial experts by asking a series of paired comparison questions. Once all the pair wise comparisons are completed, the relative importance weight for each component is determined. Given that  $A$  is the pair wise comparison matrix, the weights can be determined by expression:  $A w = \lambda_{\max} w$ , where  $\lambda_{\max}$  is the largest eigenvalue of  $A$ . Saaty [28] provides several algorithms for approximating  $w$ . In this paper a two-stage algorithm was used that involved forming a new  $n \times n$  matrix by dividing each element in a column by the sum of the column elements and then summing the elements in each row of the resultant matrix and dividing by the  $n$  elements in the row. This is referred as the process of averaging over normalized columns. In the assessment process, there may occur a problem in the transitivity or consistency of the pair wise comparisons. For an explanation on inconsistencies in relationships and their calculations see Saaty [28].

The priority vectors for each pair wise comparison matrix will be needed to complete the various supermatrix submatrices. We will need a total of 50 priority vectors to complete our supermatrix. This



requirement means that 50 pair wise comparison matrices must be completed for each case company. The pair wise comparison matrix results used were all tested for achieved the consistency goals.

- **Supermatrix formation:** ANP uses the formation of a supermatrix to allow for the resolution of the effects of the interdependence that exists between the clusters within the decision network hierarchy. The supermatrix is a partitioned matrix, where each submatrix is composed of a set of relationships between two clusters in the graphical model. A generic supermatrix of our model is shown in Figure 2, with the notation representing the various relationships from Figure 1; for instance, “A” is the submatrix representing the influence relationship between green logistics dimension elements’ and control factor of the goal of selecting a green supply chain system.

- **The solution procedure:** The supermatrix M is a reducible matrix with a multiple root, as defined by Saaty [3]. To solve for the values of the alternatives, Saaty [3] recommends that the values of M be column stochastic. That is, the sums of the columns should be normalized to equal a value of 1. To complete this task, each of the columns may either be normalized by dividing each weight in the column by the sum of that column.

The final step in the process is to obtain a priority ranking for each of the alternatives. We will determine this ranking by calculating the influence of each of the alternatives on the objective of improving the GSCM. Saaty states that a simple hierarchy and the additive solution approach is appropriate if strong dependencies among the criteria do not exist [3]. But, in this case the dependencies are considered to be strong. In addition, Schenkerman [29] has shown that the supermatrix approach is capable of reducing the occurrence of rank reversal, thus providing more accurate portrayals of decision-maker preferences. Saaty recommends a simple solution technique to solve this problem by raising the supermatrix M to a large power until convergence occurs [3]. The relative influences of the alternatives on the objective of improving the GSCM are shown in the “Goal” column. The results are obtained by using Super Decisions 1.6.0 Software ([www.superdecisions.com](http://www.superdecisions.com)).

	ALT	DFE	GL	GOA	GOAL	MP	NPD
Alternatives	0	0	0	<b>K</b>	0	<b>L</b>	0
Design For Environment	0	0	0	0	0	0	<b>F</b>
Green Logistics	0	0	<b>G</b>	0	<b>A</b>	0	<b>D</b>
Green Organizational Activities	0	0	<b>H</b>	0	0	0	0
GOAL	0	0	0	0	0	0	0
Manufacturing Priorities	0	0	<b>I</b>	0	0	0	<b>J</b>
New Product Development	0	<b>E</b>	<b>C</b>	0	0	0	<b>B</b>

FIGURE 2.

General submatrix notation for supermatrix.

The results for Hyundai-Assan show that ALT 2 has a higher priority value (with score of 0.434) than the current situation (with score of 0.294) which is better than the ALT1 (with scores of 0.272). The results for Ford-Otosan (Figure 4) show that ALT 2 has a higher priority value (with score of 0.406) than the current situation (with score of 0.354) which is better than the ALT1 (with scores of 0.240). The results for Toyota (Figure 5) show that ALT 2 has a higher priority value (with score of 0.400) than the current situation (with score of 0.344) which is better than the ALT1 (with scores of 0.255).

The obtained results show that analyzed case companies’ SCM systems are more environmentally conscious than JIT system. On the other hand, it is obvious that they have to implement some adjustments to improve their environmental performance. Hyundai-Assan’s SCM system takes the lowest ANP priority value when it is compared with other companies. So, we can say that Hyundai-Assan has to show more effort to improve his current SCM system. It is remarkable that Ford-Otosan’s and Toyota’s current SCM systems take close ANP priority values, but unfortunately they have some insufficiencies to fully adopt environmental focused supply chain management. For this reason, if Ford Otosan and Toyota manage to overcome these insufficiencies, they will be reference companies for GSCM in Turkey.

## CONCLUDING REMARKS

This paper addresses the need for a strategic analysis model to assist management in evaluating a number of alternatives for improving GSCM initiatives. Through this line, an evaluation model is developed based on a literature survey and refined with industrial experts. The proposed model is implemented in Hyundai-Assan, Ford Otosan and Toyota. The obtained results provide additional insights for research and practical applications.

The ANP method used in this study offers a more precise and accurate analysis by integrating interdependent relationships, but requires more time and effort (additional interdependency relationships increase geometrically the number of pair wise comparison matrices). For this reason, an application of the ANP approach, as proposed in this study should be targeted at more strategic decisions, especially for long-term profit and long-term competitiveness considerations.

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# A NEW FRAMEWORK FOR PORT COMPETITIVENESS: THE NETWORK APPROACH

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*Abstract - In the last decade, the port economics literature has given great emphasis to the Supply Chain Management approach as the new paradigm for the definition of port competitiveness. Nevertheless, the application of SCM approach to the port is particularly complex given the traditional hostile relationships between port actors. In the effort to overcome such complexity, some authors have considered ports as Logistics Service Providers interpreting their role within supply chains through the integrative practices undertaken by Shipping Companies and Terminal Operators in the supply of integrated logistics services. Even though these actors are crucial for the port competitiveness, they determine a passive role of port in the new competitive scenario. The definition of a potential and pro-active role of port in the supply chains is the objective of this paper that presents, through a literature review on SCM and port competitiveness, a new framework for port competitiveness.*

*Keywords - Supply Chain Management, Port competitiveness, Network approach*

## INTRODUCTION

In the last decade, the port economics literature has given great emphasis to the Supply Chain Management (SCM) as the new paradigm for port competitiveness. SCM, as managerial philosophy, supports the development of partnerships between actors of the supply chain and considers the integration of activities and resources of these actors along business processes, the source of competitive advantage. Accepting this view, some authors have reconsidered recent contributions and conceptual categories of the managerial literature on Supply Chain Management (SCM) to re-define strategic positioning and port strategies [1] - [2] - [3] - [4]. In particular, a new systematic view is being affirmed, by which the competitiveness of a port, although still strongly related to structure-type variables (geo-economic context, institutional model and the infrastructures of connection), is increasingly dependent on software components of the port business, that include the range of services offered, the ICT systems for the exchange of information between actors in the same and in other port communities, the know-how of the maritime industry, the level and intensity of relationships between actors; all elements that define the quality of a port [2] - [4] - [5]. Through a literature review on SCM and port competitiveness, this paper proposes a new theoretical framework for port development. The paper is structured in two main parts. The first part focuses on logistics integration and SCM issues in the port environment. This section of the paper is particularly outstanding, as each concept has not been dealt with univocally in literature; from an examination of these studies, it becomes evident that there is an absence of frameworks to represent the entire port community in the process of creating value. Because the port is a complex reality, involved in a series of supply chains, each of which is a specific entity with particular needs to meet, networks make it possible to describe the relationships that are created between port actors in the process of customer satisfaction. As a result, in the second part of the paper a new model is proposed that considers determinants for port competitiveness the interorganisational relationships created between the different network actors to manage various business activities and to oversee critical resources in order to satisfy the clients.

## LOGISTICS AND SCM IN THE PORT LITERATURE

In the recent debate on Port competitiveness, a growing number of papers have focused on the issue of integration of port activities in the companies' supply chains, in the attempt to frame unitarily the port in the process of creating value for the end customer [4]. The difficulties that have since been encountered in the use of a systematic approach in the port – aimed at determining the contribution of the whole port community in the supply chains - is mainly due to the lack of a “*competitive community spirit*” among the actors, both public and private. The concept of integration in the port context has essentially concerned intermodality and

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organizational integration undertaken by global carriers aimed at responding to the changing requirements of industrial and commercial enterprises and, at the same time, improving their own internal efficiency [6] - [7]. [8] - [9] - [10] - [11] - [12] [13]. Even though these two areas of study extend the field of analysis to the role and integration modes of ports within global transport systems, on the other hand they underline the passive role traditionally played by ports in relation to the strategic choices of other port community operators, with obvious effects on their bargaining power and, in general, on their development strategies. In this respect, it has already been shown that ports are mere “pawns in the game” within global transport systems and that the power of liner shipping affects port development [14]. In re-defining port positioning and strategies, Robinson [1] tries to systemise recent contributions in the SCM literature by proposing to create a new paradigm, based on the conceptual categories of the value constellation [15]. In the paper, the port is considered to be a Third Party Logistics (TPL) provider that intervenes in a series of different companies’ supply chains. Specifically, the port is a market focused firm, where all businesses are managed to provide superior value to target customer. Moreover, port’s strategic positioning choices involve two key issues [16]: what supply chain resources a port should own or control and how it should defend its ability to accumulate the value so derived. The proposed framework, innovative for the conceptual categories on which it is based, offers interesting insights on port value creation process in the supply chain; in its exemplification, the framework focuses on integrative practices undertaken by shipping companies for the supply of complex logistical services, from intermodal transport to the handling of goods. Paixão and Marlow [3] analysed the application of the agile strategy to the port sector, by focusing on the new managerial strategies undertaken by port players (mainly terminal operators) aimed at tackling the high levels of market uncertainty. By analyzing external integration, the authors, in contrast to Robinson [1], identify the role of the port in the supply chain through the contribution of the “multi-port operator”, i.e. large terminal operators, in the process of creating value. In an empirical work, Carbone and De Martino [2] have analyzed the contribution of the port of Le Havre in the Renault supply chain, according to the SCM approach. The model applied [17], was based on the assumption that a better integration between the port actors leads to a higher competitiveness of the supply chain. The research proved that relational component of port’s offer is crucial in determining port competitiveness. Finally, Bichou and Gray [4] try to conceptualise the port system from a logistics and supply chain management perspective, aiming to define a new framework to measure port performance. As to the results of their exploratory investigation (carried out on a sample of 100 experts in the port field), it is interesting to note that respondents belonging to the port community showed a lack of familiarity with logistics and SCM concepts, especially those related to logistics integration. This implies that all the models described above are still in the phase of theoretical elaboration and that their empirical implementation calls for a “cultural leap” especially with reference to Port Authority and other actors of the port community.

## **PORT COMPETITIVENESS: A NEW FRAMEWORK**

From the aforementioned literature review on port competitiveness, it becomes apparent that there is a lack of frameworks that are able to represent the complexity of the port community in the process of creating value. The Robinson’s [1] interpretation of port as Third Party Logistics provider correctly combines the creation of value to the concept of value constellations and his work represents a fundamental contribution to the definition of a model of analysis of port competitiveness. In his exemplification, however, the framework deals with value exclusively from the perspective of the shipping companies. This interpretation of port value creation seems more appropriate to describe the contribution of one single port operators in the supply chain and it neglects the advantages offered by promoting the different interactions that can exist between port actors of the supply network. Although shipping companies have a fundamental role in the port competitiveness, they cannot represent the only subject of the development options, because the port should build its success by developing activities and resources that not exclusively favour the shipping company’s distribution network, but also others port users, including the manufacturing companies of its own hinterland.

This consideration proves even closer to reality if we consider the port - marketplace relationship, i.e. the function of centrality and inter-connection that the port can play [18]. In particular, the concept of centrality refers to the flow of goods that originates in the regional economic system to which the port belongs (local hinterland). The concept of inter-connection, instead, refers to the position of the port within the intermodal routes [19]. In this case, the flow of goods does not depend on the conditions of the regional economic system, but on the relative position of the port in the distribution network of large shipping companies and multi-modal transport operators [20]. In the light of these considerations, we [21] believe that the SCM determines

the differential competencies and services' features that the port must foster, so as to promote the economic development of its own hinterland (port performing the function of centrality). Moreover, given the state of the art of SCM and port competitiveness, and considering that the port represents a complex reality, we believe that models based on a network perspective, adopting the concept of *value chain constellation*, can set the framework to determine port competitiveness. In particular, these models take all the possible modalities of interaction into consideration among a multiplicity of network actors, by analyzing the development of inter-organizational relationships in the management of business activities and resources in the process of creating value for the client. Moreover, according to these models, a major factor in strategic positioning is the relational capacity of the company. Mobilizing and combining critical resources and activities is connected to company's abilities to combine its own resources and activities with those of others [22]. Relationships are the mean by which companies access to, mobilize and combine critical resources and processes, promoting innovation and productivity in the network but also within the company.

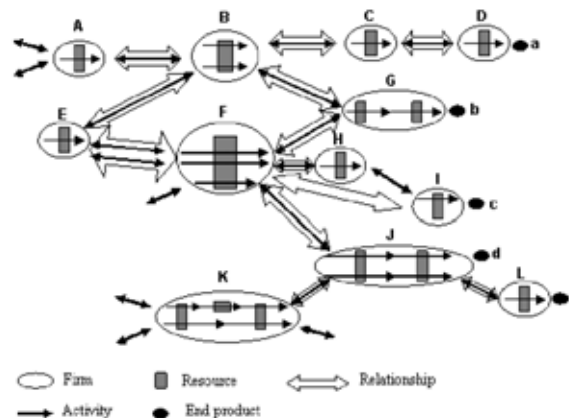
### SCM MODELS ACCORDING TO A NETWORK PERSPECTIVE

According a growing number of authors, most of SCM models emphasise the linear relationships between a focal firm, a supplier, and a customer. One major issue overlooked is that any focal organisation is normally part of several supply chains and therefore effort to optimise individual supply chains, without considering interdependencies among chains, may hamper the efficiency elsewhere in the network [23]. Recognising the existence of different interdependencies [24] between the supply chains of a network allows the company to integrate activities and resources at different levels, including that of the network. The sequential (or serial) interdependence suggests that there is a unidirectional relationship between the activities of network actors; the output of an activity represents the input of the next one [25]. Making use of these interdependencies, a company can create economies of integration. The pooled and reciprocal interdependencies between activities, resources and actors allow us to properly understand how value is co-produced by actors in a supply network [23]. In particular, the pooled interdependence between two activities shows that they are connected to a third one or that they share the same resources, and that they are thus indirectly interdependent. Exploiting pooled interdependencies can lead to economies of scale or scope: economies of scale, in the case of two activities being the same, economies of scope when the two tasks are similar. Reciprocal interdependence is the mutual exchange of input and output between two parties. This form of interdependence is closer and stronger, because every variation in activity of one party can be made if, and only if, there is a reciprocal change in activities of the other party. The advantages that can be obtained through these reciprocal interdependencies are associated to the combined capabilities of each party to resolve problems and utilise efficiently and effectively the resources of the network. Exploiting reciprocal interdependencies means "being innovative, agile and reactive to changes". The supply network structure is a field of study of considerable importance [26], as it includes the identification and description of the relationships between actors of the same network and the process of creating value for the end customer, through different interdependences [27]. Every company is a member of a set of supply chains with different roles and decision-making power. In this environment the inter-organisational relationships are considered to be the most relevant strategic resources [28], "*bridges of value*", as they give companies access to other actors' resources in the network and they strongly contribute to the value co-production [15]. Studies on the network have highlighted the aspects of interdependence and interaction between different actors involved in the creation of value. In particular, they attempt to overcome what is considered to be a traditional vision of value creation, based on the Porter value chain concept, and try to develop alternative models of interpretation, such as, value net, value network, or value creating network [29] - [30] - [31]. According to this view, the value for the client is not created by a single company, but it is co-produced in combination with other actors in the network. The greater the degree of interdependence between the network's actors, the more potential co-produced value there will be [32].

### THE APPLICATION OF DUBOIS' MODEL

From the examination of the SCM models according to a network perspective, the work presented by Dubois [33] proves to be particularly useful in representing the creation of value for the port in supply chains [34]. Dubois [33] in an effort to analyse the complex patterns of interrelated chains (a supply network), suggest a framework consisting of: products, activities and resources, firms (or business units) and relationships. Within such a framework, there are two major assumptions: (1) individual firms try to optimise their respective sets of resources and activities by taking interdependencies across boundaries into account;

and (2) the relationships between firms provide them with means to coordinate their activities and to interact in the development of the resources activated by, and of the products resulting from, their respective activities.



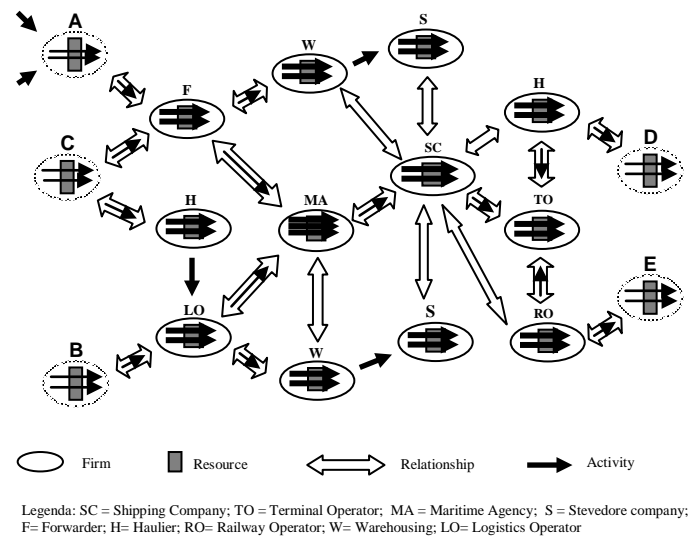
Source: Dubois [33]

FIGURE 1:  
A complex pattern of interrelated supply chains (Supply network)

Firms involved in these chains will perceive products differently (Figure 1). For example, for firm F there are three products that will follow three different supply chains and will end up in three different end products (b, c and d). For firm F there are also other products of relevance; those supplied by firm E as inputs. Firm F's activities (utilising a common resource) result in three different products that are further refined by G, H, I and J into end products b, c and d. By this way of organising the activities, the three supply chains utilise resources also activated in other chains within, for example, firms B, E, F and K. Hence, in this simplified supply network there are a number of interdependence within and among the supply chains that the actors should take into account in order to be efficient. Each firm in the network will have different perspectives on how to organise and manage their activities, resources.

This model, based on the value chain constellation concept already applied by Robinson [1], allows us to view the port as a network of actors who co-produce value by promoting different interdependencies (sequential, pooled and reciprocal) between supply chains. In fact, the port is involved in a number of supply chains (that represent the different entities to satisfy) and, contextually, the services supply in a specific supply chain is generated by different port actors (the port is a network of companies) that pursue a common strategy in satisfying the specific needs of the customer. To apply this model to the port's environment, two components of the concept of integration must be distinguished on the basis of the responsible actor for strategic decisions: firstly, the Port Authority that determines the quality of hardware components (infrastructure and their inter-connections to the market place) of the port's offer; secondly, the software component which is defined by the capabilities or the development of distinctive competencies of other port actors in managing various activities in the supply chain. Even if closely interdependent [35], the software component is considered the main determining factor in the port competitiveness, at least for industrialised countries [36]. Port Authorities – mainly in charge of the hardware dimensions of port development - have to ensure and enable the efficient management of supply chains through policy actions. These should be aimed at improving port infrastructures and their connections within existing transport systems, keeping in mind the criteria of environmental, social and economic sustainability; allowing free competition between port operators through concessions of terminals and spaces for the supply of value added services; enhancing the collaboration and coordination of port activities through IT systems; promoting the development of its own hinterland by creating economical, relational and social connections between the port and the market place. The ability of the “port” to recognise and exploit interdependencies within and between different supply chains will determine its capability to create value in supply chains. In our framework, the port is represented as a network of actors that carry out a number of activities in the supply chain in close collaboration, sharing different resources (Figure 2). The higher the level of collaboration (integration) between actors the greater the benefits that they will perceive in promoting the pooled and reciprocal interdependencies between the various supply chains. In this way, the features of the supply chain play an key role in defining the port development

policies, because they determine the importance of the resources to be controlled and the activities to carry out in the port. Only through an understanding of these needs, can the port exploit the chance of becoming an active part of the supply chains to which it belongs and thus, gain the advantages of better integration.



Source: Our elaboration

FIGURE 2:

### Port's value creation within supply network

In our specific case, firms A and C have to export their products to firms D and E, respectively. From port perspective, each supply chain represents different entity that may or may not be in conflict with each other for what the demand attributes are concerned (reliability, security, speed, destinations, etc.). In the port, many firms are involved in performing activities through different resources. For exemplification, let consider three main actors: SC, a shipping company, F a freight forwarder and TO, a terminal operator. On the basis of their level of inter-organisational relationships, the port can be viewed as a fragmented entity – in which each operator performed its own activity separately from those performed by the others actors – or a single unit – where port operators performed different activities in close synergy by sharing resources. For example, there may exist pooled interdependencies between the actors SC and F, if they use common logistics resources, such a terminal or communication systems, in order to satisfy the requirements of firm A and B. Moreover, there may exist pooled interdependencies between the two supply chains involving firm A and B, as they jointly use the port to export their products. The analysis of activities, resources, and inter-organisational relationships allows determining port actors' interaction in the management of port activities and the relative resources exploited in the value generation process. Naturally, resources and activities are completely intertwined, because resources are necessary for the undertaking of activities and have no value unless they are activated. And the way in which resources are “activated” and activities performed depends largely on the inter-organisational relationships among port operators and others actors of the supply network.

## CONCLUSION

This paper starts with the consideration that in today's competitive context, ports should define strategies and competitive positioning on the basis of a new paradigm that views the ports as actors in the supply chains. The objective is to design port development strategies within the conceptual categories of SCM, so as to define a pro-active role of the port, which is no longer linked passively to the strategic choices of the Global Players, but is a dynamic player in the competitive scenario. From the literature review, it is clear that there is a substantial “gap” between the theoretical frameworks available in the specific literature and the possibility of implementing such frameworks in the port business environment, at least in the short run. Some of the reviewed contributions, in fact, pointed out the scarce sensitivity of port operators and public authorities towards the pursuit of new forms of integration entailing cooperation with other actors and hence mutual trust. In order to overcome such a limitation, the supply network perspective allows us to correctly interpret the creation of value by the port according to a SCM approach, because the current competitive scenario requires

flexibility and an integrated approach between different activities and other players in the process of satisfying the end customer. Within such a perspective, the port has to build its competitive advantage on the development of competencies that go beyond the traditional efficient movement of cargo, but include the effective supply of value added logistics services. A determining role must therefore be played by the Port Authority that is called to identify those resources that allow the port to provide a higher quality infrastructures and services, i.e. the so called “critical assets”. As the port is part of a variety of different supply chains (that represent different entities to satisfy) and at the same time the offer of services is generated by various port players (the port is a network of companies), the work output is the definition of a framework to identify the creation of value for the port. In accordance to the new paradigm, by which competition is not played by individual companies but between supply chains, port competitiveness is determined by the quality of the entire port, both in terms of infrastructure and links to the transport systems (hardware components) and in terms of services (software components). In this context, development strategies of the Port Authority has to foster, through the creation and implementation of infrastructures of connection and access to international communication and business networks, the development and promotion of new logistics and transport businesses that are able to support different production and distribution chains. Resources play an important role as they can promote at different levels, the development of inter-organisational relationships between the various players in the supply network. In this scenario, terminals represent only one element of the Port development policies, because they cannot promote the creation of new added value logistics activities on their own. ICT systems, modal-interconnections and the acquisition of new areas, represent critical assets for the port to succeed in becoming the centre of attraction and development of new logistics and transport businesses. On the other hand, port operators perform their own activities within a supply network by using and sharing resources; in such environment, each supply chain represents a specific entity with specific needs to be satisfied. Port operators confront different requirements and their ability to exploit interdependencies among supply chains will determine extent to which port, as a complex net, creates value in such a supply network. In conclusion, the concept of value constellations represents more appropriately the value configuration approach to the diagnosis of port’s competitive advantage. Activities, resources and the level of inter-organisational relationships between the players in the network are therefore critical and essential in the port’s value creation process. In this scenario, the framework presented, that subsequently needs to be validated, represents a useful tool for the Port Authority to define new core-businesses in the port, to specify relevant core and threshold competencies that need to be developed and therefore to decide its strategic positioning in this new competitive scenario.

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# **Chapter 5**

Sustainable Transport Policies, Traffic Engineering



# CLEAN TRANSPORT: INNOVATIVE SOLUTIONS TO THE CREATION OF A MORE SUSTAINABLE URBAN TRANSPORT SYSTEM

Ela BABALIK-SUTCLIFFE<sup>1</sup>

**Abstract** — *Environmental problems at both urban and global levels have become major issues in the field of transport planning. A significant policy change took place in national and supra-national transport policy documents, which emphasize the need to improve, and increase the usage of, clean and sustainable modes of urban transport. In the past decade, transport planning in many cities around the world experienced a radical change in approach, placing increasing emphasis on public transport and non-motorized modes as well as various innovative programs for changing mobility patterns, travel behavior, and eventually raising awareness on clean transport. This paper provides an overview of a Europe-wide project on policies and implementations of individual cities regarding clean and sustainable urban transport. The project has helped to gather a large number of best-practice cases, a selection of which are presented in this paper in order to provide a better understanding of the wide spectrum of possible plans, projects and programs that local governments can implement to create a cleaner and more sustainable urban transport system.*

**Keywords** — *Sustainable transport, clean transport, best-practice, ELTIS*

## INTRODUCTION

The transport sector is one of the main contributors to environmental problems, such as global warming, greenhouse effects and the rapid consumption of non-renewable resources. It is clear that the way we plan and operate transport systems has to change if we are to comply with the objectives of sustainable development [1]. Such a policy change has taken place in many parts of the world, with sustainable and clean transport objectives becoming an integral part of most national and supranational policy documents. With the Brundtland Report [2] in 1987, the Earth Summit [3] in Rio de Janeiro in 1992, and the Kyoto Protocol [4] in 1998, the need to attain a more sustainable development and the need to minimise the negative effects of development on the environment became universally-acknowledged objectives. The Habitat II meeting in Istanbul in 1996 and the OECD Conference [5] on sustainable transport in the same year in Vancouver brought arguments for sustainability to the forefront of urban planning. The 2001 Habitat document [6] on the role of urban transport on sustainable human settlements development helped to highlight the importance of the transport sector in attaining sustainability goals, while the World Bank Urban Transport Strategy [7] published in 2002 provided a framework for urban transport planning with its focus on the effects of transport on urban development, the environment, and poverty reduction, as well as the importance of mass rapid transportation, public road passenger transport, non-motorised transport, and techniques for demand management, traffic management and pricing. The 2001 EU Transport White Paper also emphasised the need to create a more balanced transport system in which clean transport modes should play an increasingly important role. The 2007 EU Green Paper on urban mobility [8] further highlighted the importance of clean transport and the potential provided by non-motorised modes.

These policy documents helped to shape urban transport policies in most European countries; and as a result, reducing petrol-dependency, emissions, congestion and bottlenecks, and at the same time improving accessibility, environment and quality of life became priority objectives. There is broad agreement that public transport systems and non-motorised modes of transport must be improved if the use of these more environmentally-friendly modes is to be encouraged and accessibility ensured for all. It is also important that such improvement schemes are introduced together with restrictions on car usage, such as congestion charging, parking control and management, pedestrianisation, car-free residential areas, etc., with a view to increasing their impact on mode choice and traffic reduction [9]. The governments of many European countries have introduced policy documents to steer policymaking and implementations towards these approaches for more sustainable transport systems. UK policy documents are noteworthy in this regard: the Planning Policy Guidance on Transport [10] provides an explicit emphasis on the need to promote more

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sustainable transport choices and to reduce the need for travel, especially by car. The 1998 UK White Paper on transport had a clear emphasis on sustainable and clean transport, as well as the need to abandon road programmes; while the White Paper in 2004 highlighted strategies for clean transport, i.e. making walking and cycling a real alternative for local trips, and improving public transport. The government also provided guidelines for local authorities on ways to encourage walking [11]. While such national policy documents may be fewer in number in other European countries, there has been, nevertheless, a significant shift in policies towards clean transport, affecting the nature of projects and regulations in urban transport.

This paper provides an overview of such projects implemented in European cities, representing the radical change from the road- and car-oriented transport programmes of the past. These are examples of innovative solutions in creating a sustainable clean urban transport system, and the cases are selected from a vast list of best-practice cases gathered through a Europe-wide project on clean urban transport. The project, which aims to encourage the sharing of practices and gains of various cities in their attempt to transform their transport planning approach, have helped to gather a large number of best-practice cases, largely from Europe but also from other parts of the world, with the underlying objective of helping other cities towards more sustainable solutions in urban transport, and raising the awareness of city governments, as well as citizens<sup>2</sup>.

The case studies presented in this paper are those that the Middle East Technical University's working team, as the Turkish section of the mentioned project, had focused upon: firstly, a number of best-practice cases from Europe were selected to be shared and disseminated among local governments in Turkey; and secondly the best-practice cases from Turkey were gathered to be included in the project. Through these two sets of case studies, the paper also helps to facilitate a comparison of urban transport planning approaches in European and Turkish cities.

## **BEST-PRACTICE CASES FROM EUROPE**

Innovative solutions for a sustainable green transport system cover a wide and diverse set of policies and projects. The cases gathered as best-practices in the project are categorised under such project headings as: clean and energy-efficient vehicles; public transport improvements; cycling; walking; demand management and pricing; mobility management and travel awareness; transport and land-use planning, etc. In this section, innovative projects that represent contemporary planning approaches in urban transport are presented.

### **Projects for Clean and Energy-Efficient Vehicles**

The introduction of public transport vehicles that run on alternative “green” fuels is one of the major areas for intervention in the creation of sustainable urban transport. Diesel, natural gas and biogas are some of the alternatives available to help reduce the air pollution created by public transport buses. Hydrogen buses were introduced in Reykjavik, Iceland; Trolleybuses running partially on batteries were introduced in Landskrona, Sweden; not only public transport buses, but also taxis and private company vehicles were encouraged, through incentives such as free parking and a priority taxi lane, to convert to natural gas in Gothenburg, Sweden. Similarly, electric cars were offered as rental vehicles in the city centre in Trento, Italy; and electric scooters and hybrid passenger cars were introduced as part of a trial project to test the affects on air quality in Thessalonica, Greece. All these projects were aimed at encouraging the use of renewable energy sources and reducing emissions and air pollution.

### **Projects to Improve Public Transport Systems**

Most cities worldwide are investing in their public transport systems to increase the service quality with a view to attracting more passengers, and in particular to create a modal shift from private cars to public transport. New metros, light rail and tram systems have been introduced in many cities, not only in Europe, but in all parts of the world. Such urban rail investments have been extremely popular with local governments; however, there is also an increasing recognition that the improvement of bus systems, through the introduction of busways, buslanes and bus priority schemes, can be equally effective and at much lower costs. In addition to these infrastructure investments, a relatively new approach that has been seen in several European cities is the introduction of information or mobility centres, which provide travel information and travel plans to both residents and visitors. Such centres not only provide information on the transport services of the cities, but

<sup>2</sup> These individual experiences and cases are listed in the wide case study database of the European Local Transport Information System [ELTIS] webpage at [www.eltis.org](http://www.eltis.org), which is one of the main intended outcomes of the project.

also raise awareness on sustainable alternatives in traveling and encourage users to choose public transport, cycling and walking in their trips.

### **Cycling**

Cycling is considered as not only a sustainable travel alternative in urban transport, but also a means of introducing regular exercise into the daily lives of a country's population. In this respect, cycle lanes and networks have been introduced and expanded in cities in Belgium, the United Kingdom, Bulgaria, Croatia, the Czech Republic, Denmark, the Netherlands, Finland, France, Hungary, Italy, Poland and Serbia. Taking this one step further, free or rental bicycle points have been introduced throughout the urban areas (and especially at urban rail station sites) of many cities, including Paris and Lyon in France; all of the Randstad area in the Netherlands; Munich, Berlin, Frankfurt, Cologne, Stuttgart and Karlsruhe in Germany; Leuven in Belgium; Bern, Genf, Lausanne, Thun and Zurich in Switzerland; and in a number of cities of Italy and Spain. The latter measure aims to incorporate cycling into commuter trips in integration with public transport journeys. In addition, many cities have launched competitions and campaigns to encourage their citizens to use cycling as a daily transport mode to increase their health values.

### **Walking**

Pedestrianisation schemes and the improvement of pedestrian routes and zones have become widespread in many European cities. Cities of Belgium, France, Denmark and the Netherlands have played a pioneering role in the pedestrianisation of their city centres. However, schemes to promote walking do not have to bring about full pedestrianisation: improvements of sidewalks in terms of their width, pavement quality, cleanliness, lighting and better accessibility through ramps have been regarded as effective measures. In several cases, such improvement schemes have been integrated with 'Safe Routes to School' concepts, which help to create a safe and pedestrian-friendly network in accessing schools. In such schemes, as well as in other parts of urban areas, traffic calming measures have been implemented to reduce traffic speeds and create safer roads for walkers and cyclists. The 'Home Zones' scheme was launched in the UK, inspired by the Woonerf concept, with a view to reclaiming the streets in residential neighbourhoods and creating safe open spaces for children to play and for communities to gather. In addition to all of these improvement schemes, campaigns, education programs and games for schoolchildren have been introduced to encourage people to walk more.

### **Demand Management and Pricing**

While improvements in public transport, cycling and walking are important in sustainable transport planning, alone they are not effective in creating a modal shift from the private car to these more sustainable modes of travel. It is essential that such schemes are supported by measures that make driving into the city centre more difficult, expensive, and therefore less attractive and convenient. Closing certain roads and zones to motorised traffic is one way of making driving more difficult; and hence pedestrianisation schemes can help discourage car usage in central urban areas. In addition, European cities have opted increasingly for measures to make it more expensive to drive into the city centre. Parking fee schemes have been introduced in to increase the cost of driving into the city centre, backed by the introduction of park and ride systems. More importantly, congestion charging has come to be considered as an effective measure: the introduction of such a scheme in London, UK, in 2003 helped to raise revenues for public transport and decreased traffic in the central zone, although causing overcrowding on the public transport system. Provided that public transport is also improved, congestion charging can indeed result in significant reductions in traffic, and such schemes have also been adopted in Stockholm, Sweden in 2006; and in Valletta, Malta in 2007.

### **Awareness-Raising Campaigns**

Awareness-raising campaigns are not a new concept in urban transport, with campaigns for traffic safety, driver behaviour and the wearing of seatbelts being widespread around the world. However, today there are an increasing number of awareness-raising campaigns to encourage citizens to make sustainable travel choices, aimed at increasing the awareness of all target groups (schoolchildren, parents, university students, residents, etc.) of the consequences of their travel decisions and transport mode choices. Street festivals and one-day closures of selected residential streets have been carried out in many cities, particularly in conjunction with Home Zones projects. In addition, education programs and games directed at schoolchildren have become widespread: The Snakegame [12] was tried out in Belgian schools to encourage schoolchildren to make

sustainable travel choices within a game; Mobility Week workshops [13] and orienteering games were carried out in schools in Switzerland; a short movie competition [14] was held among university students in Belgium to allow them express their thoughts on transport, the environment and sustainability; and similarly a marketing competition [15] was held among university students in the Netherlands to stimulate them to discover ways of promoting and ‘selling’ sustainable transport alternatives. Competitions and health programs have also been launched in cities to encourage citizens to cycle and walk to their places of work or education with a view to improving health. Furthermore, many cities in Europe encourage, and in some cases oblige, companies and schools to prepare ‘Travel Plans’ that inform employees and students about sustainable travel alternatives.

### **Transport and Land-Use Planning**

While there are various transport measures that can help reduce traffic in towns, it is increasingly recognised that land-use planning is one of the most effective tools in changing travel behaviours and encouraging more walking, cycling and public transport usage. It is well documented that urban rail investments cannot be successful unless there is vigorous planning action by local governments to increase development densities along these systems, and create transit-oriented and pedestrian-friendly developments around the stations [16, 17]. The integration of light rail investment and land-use planning in Portland, Oregon, US, has long been a best-practice case, illustrating that traffic reduction can be achieved when the light rail line is planned as a major urban development corridor, and when transit-oriented design approaches are implemented at station sites. In addition to using land-use planning in support of public transport investments, good public transport access can be a tool in creating land-use patterns that can eliminate car traffic. ‘Car-Free Settlements’ have been developed in a number of European cities: ‘car-reduced living’ projects have been introduced in Berlin in Germany and Zurich in Switzerland; and car-free residential areas have been planned and successfully implemented in Bremen, Cologne, Freiburg and Hamburg in Germany; as well as in Amsterdam in the Netherlands; Camden, Edinburgh and Surrey in the UK; Gent in Belgium; Vienna in Austria; etc. Experiences in these cities reveal that car-free and car-reduced residential areas can be successful and popular, provided that they are well supported with good public transport systems.

## **EXPERIENCE OF TURKISH LOCAL GOVERNMENTS WITH SUSTAINABLE AND GREEN TRANSPORT**

### **Projects for Clean and Energy-Efficient Vehicles**

Buses that run on natural gas have been introduced in many cities. Ankara introduced both diesel and natural gas buses as a measure to reduce air pollution in the city. In Istanbul, a ‘Clean Fuels/Clean Vehicles’ project has been launched to investigate transport-based emissions and introduce mitigation measures. The first phase of the project was a transport emissions inventory; based on the outcomes of this phase, plans are now being made to reduce transport-based emissions in the city.

### **Projects to Improve Public Transport Systems**

In terms of public transport improvements, perhaps similar to many cities in the world, there is growing interest in urban rail systems in Turkey. Cities, such as Ankara, Istanbul, Izmir, Bursa, Antalya, Eskişehir, Konya and Kayseri have all opted to introduce urban rail systems, however not all these cases can be considered as best-practices, as there is very little interest in integrating some of these systems with land-use planning, or supporting them with measures to restrict and discourage car usage.

The tram system in Eskişehir is one of the best-practice cases, with its high ridership throughout the day, and its positive impact on mobility and accessibility in the city centre. Two of the city centre’s main boulevards have been allocated to the tram system, and have thus been closed to motorized traffic. This has been complemented by further pedestrianisation projects in the centre, creating a pleasant, although limited, network of car-free streets. In addition, regeneration and redevelopment projects were implemented at the same time; and the Porsuk River, which runs through the centre of the city, has been rehabilitated and its surroundings integrated into the pedestrian system. All these projects altered the overall physical appearance of the city centre, resulting in reduced traffic and emissions, and increased walking and public transport usage.

The Izmir light rail system is also a best-practice case, being introduced as part of a wider package of projects under the ‘Transformation in Transportation’ Project. The ferries, which were previously under-

utilized, underwent renewal and were integrated with the new light rail stations and bus stops; bus routes were restructured and feeder buses were introduced for the light rail system; and a new fare and ticketing system was launched. As a result, public transport usage has increased significantly: ridership of the ferries and light rail has increased, while bus travel, which decreased initially due to the extensive restructuring, has again increased, which is testament to the potential of a well-integrated public transport system.

Busways and buslanes are the least common forms of public transport improvement in Turkish cities, despite their proven success in a number of European cities. It would appear that the popularity of urban rail alternatives overshadow busway options. It is only in Istanbul that a busway project has been implemented, and recently extended, along an important traffic demand corridor: the system provided a high quality service, and more importantly significant time savings in this heavily-congested corridor.

### **Cycling**

Projects to introduce bicycle lanes and networks are rather limited in Turkish cities. Konya is the only city with an extensive cycle lane network, currently measuring over 60 km and planned to be further expanded in the near future. Konya enjoys a rather flat topography, which has resulted in a cycling tradition among its citizens; however, the local government has also been promoting cycling in the city, both through the network expansion, and through annual cycling festivals. In addition to Konya, the Nilufer district in Bursa has also launched a project to create an extensive cycling network, with plans to introduce cycle parks at LRT stops.

### **Walking**

Walking accounts for more than 20 percent of trips in most metropolitan cities in Turkey, and more in smaller cities. Nevertheless, the current infrastructure for walking, i.e. pedestrian road network, pedestrian zones, and even the physical quality of sidewalks are extremely poor, with no plans for improvement evident among the local authorities. Eskişehir, as mentioned earlier, is one of the few examples where major traffic corridors in the city centre have been closed to motorized traffic, becoming tram-only roads with wide pedestrian areas. In addition, in Şanlıurfa a project has been applied to widen and enhance the physical quality of the sidewalks: a busy and congested road has been converted into a one-way street, allowing for a significant expansion of the pedestrian sidewalks. In addition, the road has been cobbled to decrease vehicle speeds, and on-street parking has been restricted. After the scheme, pedestrian volume significantly increased, particularly among women and the elderly, which is testament to the sense of increased safety and security. These examples, however, remain as exceptions, rather than the rule. Most metropolitan cities choose to increase the capacity of vehicle roads in the city centres, resulting in narrower sidewalks, making walking an inconvenient and insecure mode. Turkey has no example either of 'Home Zones' or 'Safe Routes to School'.

### **Demand Management and Pricing**

Parking fees in the city centre appear to be the only management and pricing measure in Turkish cities, although this would appear to be aimed more at raising revenue than a means of discouraging motorists from driving into the city centre. Park and ride schemes are also limited.

### **Awareness Raising Campaigns**

Awareness raising campaigns for sustainable transport are also limited. Besides the annual cycling festival in Konya, the most important event has been 'The Streets Belong To Us', held in Istanbul throughout 2007, in conjunction with the 'Towards Carfree Cities Conference' held in Istanbul in September 2007 by the World Carfree Network. Organized by the Mimar Sinan Fine Arts Academy in Istanbul, the Turkish Association of Road Traffic Accident Victims, and the World Carfree Network, each month a residential street in Istanbul was closed to traffic for a day (on Sundays); and various activities were held to show the residents how they can benefit from their streets as a safe open urban space. The event proved to be very popular, creating a safe open area for a day in which children could play and the local community could gather.

### **Transport and Land-Use Planning**

While urban rail systems are proposed by many cities, they are seldom integrated into the metropolitan and regional plans, and once the rail systems are put in place, it is seldom that local plans are formulated to support these investments. The Ankara metro system was designed alongside the metropolitan plan of the city,

and therefore took place along the main development corridor of the city. However, after its construction, the location of the metro line was not taken into account in the local development plans. The Eskişehir tram system was implemented alongside with urban regeneration projects; however, its integration into the wider metropolitan development policies and projects of the city has been rather limited. In addition, no local governments have experimented with 'car-reduced' or 'carfree' living, aside from the Princes' Islands in Istanbul, which have been transformed into carfree settlements, revealing how the elimination of motorized traffic can create a smoke-free, noise-free and clean environment. However, these are islands, which make the implementation of such a scheme easier, and so far there have been no attempts to transfer this experience to new residential development areas.

## COMPARISON AND CONCLUSIONS

The review of European best-practice cases shows that urban transport planning has indeed gone through a significant transformation, and that many projects and schemes that were once considered radical and unacceptable are now being implemented in many cities with promising results. Urban transport systems and policymaking are required to go through a significant shift in order to comply with the objectives of sustainability; and it appears that this shift has already taken place in a number of countries in Europe.

In the case of Turkey, it is evident that some best-practice cases have been introduced, mostly notable in the development of new urban rail systems. However, the experience of local authorities in other measures towards sustainable urban transport is inadequate. Projects for improving and encouraging cycling and walking, the two most important modes for sustainable transport, remain limited, along with demand management and awareness raising campaigns. Nevertheless, there have been some promising examples of local campaigns in this regard, among which can be listed 'The Streets Belong to Us' in Istanbul, and the annual cycling festival in Konya.

The ELTIS project can be considered as an inventory study, and is an important platform for the presentation of contemporary planning approaches in sustainable urban transport. The comparison of the experiences of Turkish local authorities against this inventory is helpful in showing the strengths as well as weaknesses and shortfalls in urban transport planning and policymaking in Turkey.

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# EFFECTS OF URBAN BOTTLENECKS ON HIGHWAY TRAFFIC CONGESTION: CASE STUDY OF ISTANBUL, TURKEY

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*Abstract— This paper presents findings of a study which analyzed the effects of highway bottlenecks on urban traffic congestion as a side product of a large-scale project in which a “speed-delay study” was conducted for the development and calibration of a “Travel Demand Model (TDM)” for the city of Istanbul, Turkey. Speed-travel time data were collected on- and off-peak travel times of a weekday as well as weekends using the maximum-car method on toll roads, highways and major arterials of the city. The analysis of speed-travel time data revealed that the worst delays and longest queues were observed at crash locations (travel time index, TTI, varied between 4.20 and 17.8) since they were unexpected incidents with little chance to avoid without an advanced drivers information system in order to warn and re-route the upstream traffic. The worst case among the observed incidents caused long delays was the accident occurrence on a divided highway, D100 (E-5) at a 6-lane section (TTI=17.8). Capacity decreases due to road constructions was also as bad as the traffic flow blockages due to accident occurrences (TTI is varied between 3.82 and 4).*

*Key words: bottleneck, floating/maximum car method, Istanbul, traffic congestion, travel time..*

## 1. INTRODUCTION

Economic consequences of the urban traffic congestion are reached to tremendous points in terms of external costs due to lost time in daily traffic. The annual total cost of traffic congestion in Istanbul is estimated to be 3.12 billion US\$. The annual average traffic delay per capita in Istanbul is 73.9 hours whereas this figure is 51 hours in Los Angeles which has the same size as Istanbul in terms of the urban population and experience a severe traffic congestion in the urbanized area. A recent study revealed that the annual cost of the traffic congestion in Istanbul is estimated to be 144,713,430 vehicle-hour delay, 1,034,701,022 person-hour delay, and additional fuel consumption of 441,217,731 liters [1].

As for the world-wide consequences of traffic congestion, the 2004 Annual Mobility Report of Texas Transportation Institute [2] has reported concerning results. Regarding the 85 major urban areas in the US, urban congestion has been increasing everywhere in areas of all sizes and thus, longer portions of the day as well as more travelers and goods are affected by congestion. While 32 percent of the total peak period was congested in the 85 major urban areas in 1982, this ratio has increased to 67 percent in 2002 by an increase more than 100% in 20 years' time. Therefore, the total time that is spent stuck in traffic has risen from 0.7 billion hours in 1982 to 3.5 billion hours in 2002. Likewise, additional fuel consumption due to traffic congestion was 1.2 billion gallons in 1982 while it increased to 5.7 billion gallon in 2002. Besides, the total annual cost of traffic congestion, which was estimated to be 14.2 billion US\$ in 1982, increased by more than four times and reached to 61.0 billion US\$ in 2001 [3] and then increased further by 3.6 per cent to 63.2 billion US\$ in 2002. Moreover, the total traffic delay in the 85 major urban areas in 2002 was 3.5 billion hours, which is annually equivalent to a total delay of approximately 400,000 years or 46 hours per individual [2].

Another significant effect of the remarkable increase in traffic congestion is that the average weekday peak period trip takes 37 percent longer than the same trip during the off-peak period whereas it used to be only 12 percent longer in 1982. 45 percent of the traffic congestion is led by recurring problems including insufficient capacity, improper signal timing and inadequate utilization of intelligent transportation systems. Table 1 summarizes the causes of the traffic congestion and clearly depicts that bottlenecks is the number one source of traffic congestion in the US with 42 percent [4].

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TABLE 1  
Major Sources of Traffic Congestion in the US [4]

Source of traffic congestion	Percent
Bottlenecks	42
Traffic incidents	26
Bad weather	16
Highway repair and maintenance sources	11
Improper signal timing	5

This study researched the effect of bottlenecks on travel times on major highways and arterials of the city of Istanbul. Travel time data collected on- and off-peak times of day using the maximum-car method. Bottlenecks are defined as the roadway segments where the number of lanes serving the traffic suddenly decreased, and as the toll booths on the access-controlled road segments (toll roads) where vehicles have to slow down while passing through automated passing booths (called OGS, Automated Passing System, in Turkish) or come to a complete stop at cash (manual) or magnetic card reader (called KGS, With Card Passing System, in Turkish) booths. Besides, temporary bottlenecks that are created by the incidents such lane drops or lane shifts due to road or infrastructure constructions and by crashes are also included in the analysis. The paper is organized as follows: The next section describes the methodology of the research study. Data analysis and results are offered in section 3. Summary and conclusions are offered in the last section.

## 2. METHODOLOGY

Floating car method is used to collect the travel time data. A compact sedan car is run to collect travel times during different time periods between major intersections and interchanges, and then the speed is calculated based upon the distances obtained from the highway network seen in Figure 2.

### 2.1. Data Collection

Travel time data collected at the bottlenecks which are defined in the next section fall into one or more of the following time periods starting 24<sup>th</sup> of April, 2006 until the schools are closed for summer on 16<sup>th</sup> of June, 2006:

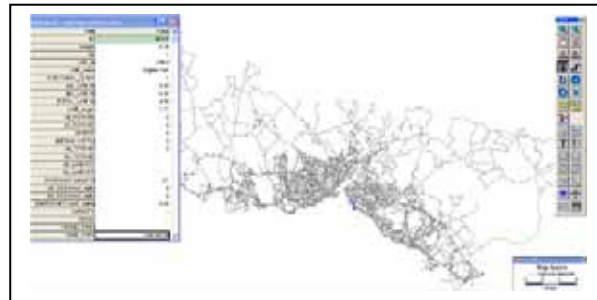


FIGURE 2  
Highway Network of the City of Istanbul.

1. Morning peak period (07 am-10 am)
2. Morning off-peak period (10 am-12 pm)
3. Noon peak period (12 pm-2 pm)
4. Afternoon off-peak period (2 pm-5 pm)
5. Afternoon peak-period (5 pm-8 pm)
6. Evening period (8 pm-10 pm)
7. Weekend (Saturday or Sunday or both)

A simple Visual Basic code written in MS Excel was operated on a portable computer to record travel times between major interchanges and at-grade intersections while traveling along

predetermined routes during the defined time periods above. A view of the Excel sheet created to facilitate the management of data collection is shown in Figure 3.

[illegible]

FIGURE 3  
Excel Sheet to Record Travel Times Along Predetermined Routes.

## 2.2. Bottlenecks

There are two major bottlenecks in the middle of the city connecting one side to another; namely, Bogazici (Bosporus) and Fatih Sultan Mehmet (FSM) Bridges. Temporary bottlenecks created by incidents such lane drops or shifts due to road/interchange constructions and by accident occurrences were also included in the analysis. They are itemized as follows:

1. Major bottlenecks
  - a. Bogazici (Bosporus) Bridge
  - b. Fatih Sultan Mehmet (FSM) Bridge
2. Temporary bottlenecks
  - a. Lane drop/shift due to construction
    - i. new bridge construction on westbound Highway D100 (E-5)
    - ii. reconstruction of Gulsuyu Interchange on eastbound Highway D100 (E-5)
    - iii. repavement on Northbound Beykoz Shore Road (Minor Arterial)
  - b. Accident occurrences
    - i. on southbound Cekmekoy-Sarigazi Interchange (Minor Arterial)
    - ii. on westbound Minibus (Bagdat) St (Minor Arterial)
    - iii. on westbound Highway D100 (E-5) at Maltepe Interchange.

### 3. DATA ANALYSIS AND RESULTS

### 3.1. Major Bottlenecks

Major bottlenecks studied in this paper are the two major bridges connecting both sides of the city; namely, Bogazici (Bosporus) and Fatih Sultan Mehmet (FSM) bridges.

### 3.1.1. *Bogazici (Bosporus) Bridge*

Bogazici or Bosphorus bridge also called 1st Bridge opened in 1973 creates two bottlenecks: one for the flow from Europe to Asia side (toll booths exist at the Asia side of the bridge), and the other for the flow from Asia to Europe side (toll booths do exist at neither side of the bridge) as seen in Figure 4.



FIGURE 4

Bogazici (Bosporus) Bridge-2x3 Lanes (the 1<sup>st</sup> bridge connecting both sides of the city opened in 1973).

Speeds observed on Bogazici Bridge during different time periods are given in Table 1. It should be noted that the major flow on the bridge Europe to Asia occurs in the afternoon periods. During the morning peak period (7 am-10 am) the speed of upstream flow (77 km/hr) was only 9.4% lower than that of the downstream flow (85 km/hr). The speed on the bridge was fairly high as 69 km/hr. These measurements although descriptively fell into the morning peak-period, they were taken after 9:45 am, so close to the end of the morning peak-period. Thus, the travel time at the upstream section was only 10% higher than that of the downstream (travel time index or TTI =1.10, which is defined as the downstream speed divided by the speed on the section) and it would not be wrong if data are considered to be the morning off-peak data. However, during the afternoon off-peak period (2pm-5pm) TTI at the upstream varied between 3.64 and 6.17. For the flow from Europe to Asia, the most critical time period was afternoon off-peak (2 pm-5pm) because travelers expecting high congestion after 5 pm tend to cross the bridge earlier. The second most highly traveled period was

TABLE 1  
Speeds Observed on Bogazici (Bosporus) Bridge During Different Time Periods

Direction	Time Period	Section (No. of observations)	Ave. Speeds Measured	Travel Speed Index*	Travel Time Index+
(1)	(2)	(3)	(4)	(5)	(6)
Europe to Asia	Morning (off-) Peak	Upstream (1)	77	0.91	1.10
		On the bridge (1)	69	0.81	1.23
		Downstream (1)	85	1	1
	Afternoon off-peak	Upstream (2)	12 ; 22	0.16 ; 0.28	6.17 ; 3.64
		On the bridge (2)	65 ; 61	0.88 ; 0.76	1.14 ; 1.31
		Downstream (2)	74 ; 80	1 ; 1	1 ; 1
	Afternoon Peak	Upstream (2)	30 ; 24	0.47 ; 0.45	2.13 ; 2.21
		On the bridge (2)	30 ; 48	0.47 ; 0.91	2.13 ; 1.10
		Downstream 2()	64 ; 53	1 ; 1	1 ; 1
	Evening	Upstream (1)	15	0.21	4.73
		On the bridge (1)	43	0.61	1.65
		Downstream (1)	71	1	1
	Weekend	Upstream (1)	92	0.99	1.01
		On the bridge (1)	99	1.06	0.94
		Downstream (1)	93	1	1
Asia to Europe	Morning Peak	Upstream (3)	21 ; 21 ; 21	0.26;0.25;0.26	3.81 ; 4 ; 3.81
		On the bridge (3)	53 ; 55 ; 53	0.66;55;0.66	1.51;55;1.51
		Downstream (3)	80 ; 84 ; 80	1 ; 1 ; 1	1 ; 1 ; 1
	Noon Peak	Upstream (2)	55 ; 58	0.58 ; 0.98	1.73 ; 1.02
		On the bridge (2)	57 ; 51	0.60 ; 0.86	1.67 ; 1.16
		Downstream (2)	95 ; 59	1 ; 1	1 ; 1
	Afternoon Peak	Upstream (1)	55	0.58	1.73
		On the bridge (1)	40	0.42	2.38

	Downstream (1)	95	1	1
	Upstream (2)	48 ; 33	0.69 ; 0.52	1.46 ; 1.94
Weekend	On the bridge (2)	53 ; 61	0.76 ; 0.95	1.32 ; 1.05
	Downstream (2)	70 ; 64	1 ; 1	1 ; 1

+: Travel Speed Index equals to the speed on the section divided by the downstream speed.

+: Travel Time Index equals to the downstream speed divided by the speed on the section.

evening time (after 8 pm). Travelers definitely choose this bridge to cross the Bosphorus during off-peak periods because it is the shorter path from Europe to Asia side of the city for the commuters whose origins or destinations are close to the route of the Highway D100 (E-5) which is connected to Bosphorus Bridge. During afternoon peak period, TTI varied between 2.13 and 2.21. Travelers who expect high congestion during the peak period, they tend to use FSM Bridge to cross the Bosphorus.

For the flow from Asia to Europe side, the major flow occurs in the morning periods as expected the TTI of the upstream flow varied between 3.81 and 4. In the afternoon peak period, the bridge was more congested than the upstream section.

### 3.1.2. Fatih Sultan Mehmet (FSM) Bridge

Fatih Sultan Mehmet or FSM Bridge also called 2<sup>nd</sup> Bridge creates two bottlenecks: one for the flow from Europe to Asia side (toll booths exist at the Europe side of the bridge), and the other for the flow from Asia to Europe side (toll booths do exist at neither side of the bridge) as seen in Figure 5.



FIGURE 5

Fatih Sultan Mehmet (FSM) Bridge- 2x4 Lanes (the 2<sup>nd</sup> bridge connecting both sides of the city opened in 1989).

Speeds observed on FSM Bridge during different time periods are given in Table 2. It should be noted that the major flow on the bridge Europe to Asia occurs in the afternoon peak period (5 pm-8 pm). There are five speed measurements during the period and TTI varied between 1.19 and 12.67. The highest two values (11.38 and 12.67) belong to the two days when heavy vehicles are unusually allowed to cross the bridge during that period. Other times heavy vehicles are held up by the police until the end of the peak-period (8 pm).

For the flow from Asia to Europe side of the city, TTI at FSM Bridge (2.33) was lower than that at Bosphorus Bridge (3.81-4) during the morning peak period as expected because Bosphorus Bridge provides the shorter route to cross the Bosphorus Strait and most travelers choose that one.

## 3.2. Temporary Bottlenecks

### 3.2.1. Lane Drop/Shift Due to Construction

**3.2.1.1. New Bridge Construction on Westbound Highway D100 (E-5)** A lane drop/shift 1300 m after Pendik Interchange on westbound Highway D100 (E-5) between Pendik and Kartal interchanges as seen in Figure 6 caused a tremendous decrease in travel speed. Speeds observed on the site are given in Table 3.

TABLE 2  
Speeds Observed on FSM Bridge During Different Time Periods

Direction	Time Period	Section (No. of observations)	Ave. Speeds Measured	Travel Speed Index*	Travel Time Index+
(1)	(2)	(3)	(4)	(5)	(6)
Europe to Asia	Afternoon Peak	Upstream (5)	69;25;75;80;60	0.82 ;0.74 ; 0.84 0.090 ; 0.080	1.22 ; 1.36 ; 1.19 11.380 ; 12.670
		On the bridge (5)	76;55;75;35;63	0.90 ;1.62; 0.84 0.38 ; 0.83	1.11 ; 0.62 ; 1.19 2.60 ; 1.21
		Downstream (5)	84;34;89;91;76	1 ; 1 ; 1 ; 1 ; 1	1 ; 1 ; 1 ; 1 ; 1
Asia to Europe	Morning Peak	Upstream (1)	24	0.43	2.33
		On the bridge (1)	65	1.16	0.86
		Downstream (1)	56	1	1
	Noon Peak	Upstream (1)	79	0.80	1.24
		On the bridge (1)	82	0.83	1.21
		Downstream (1)	99	1	1
	Afternoon off-peak	Upstream (1)	111	1.14	0.87
		On the bridge (1)	102	1.05	0.95
		Downstream (1)	97	1	1
	Weekend	Upstream (1)	108	0.84	1.19
		On the bridge (1)	104	0.81	1.23
		Downstream (1)	128	1	1

\*: Travel Speed Index equals to the speed on the section divided by the downstream speed.

+: Travel Time Index equals to the downstream speed divided by the speed on the section.

0: These number denote the speed measurements between the toll booths and the bridge where the vehicles pass through 16 toll booths and then get fit into 4 lanes on the bridge.



FIGURE 6  
Temporary Bottleneck on Westbound Highway D100 (E-5) due to New Bridge Construction Between Pendik and Kartal Interchanges.

TABLE 3  
Speeds Observed on Westbound Highway D100 (E-5) Between Pendik and Kartal Interchanges

Time Period	Section (No. of observations)	Ave. Speeds Measured (km/hr)	Travel Speed Index*	Travel Time Index+
(1)	(2)	(3)	(4)	(5)
Morning off-peak	Upstream (1)	16	0.25	4
	Downstream (1)	64	1	1

\*: Travel Speed Index equals to the speed on the section divided by the downstream speed.

+: Travel Time Index equals to the downstream speed divided by the speed on the section.

The incident (capacity decrease due to lane drop/shift) of new bridge construction on westbound Highway D100 (E-5) resulted the Travel Speed and Travel Time Indexes at the upstream location as 0.25 and 4, respectively. This means while the speed is decreased to 16 km/hr, the travel time is increased by 4 times at the upstream.

**3.2.1.2. Reconstruction of Gulsuyu Interchange on Eastbound Highway D100 (E-5)** A lane drop/shift on eastbound Highway D100 (E-5) as seen in Figure 7 caused a significant decrease in travel speed. Speeds observed on the site are given in Table 4.

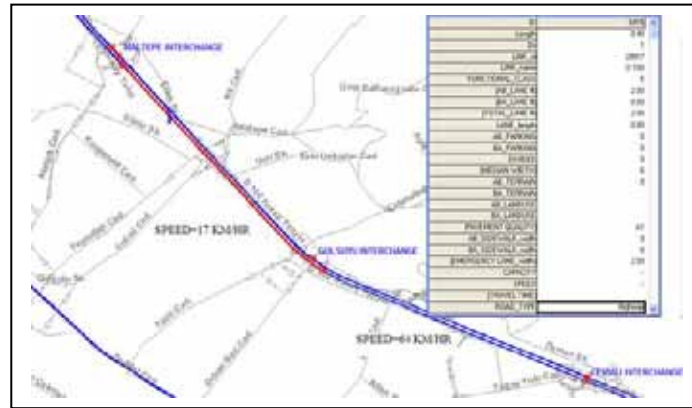


FIGURE 7

### Temporary Bottleneck at Gulsuyu Interchange on Eastbound Highway D100 (E-5).

TABLE 4

Speeds Observed at Gulsuyu Interchange on Eastbound Highway D100 (E-5)

Time Period	Section (No. of observations)	Ave. Speeds Measured (km/hr)	Travel Speed Index*	Travel Time Index+
(1)	(2)	(3)	(4)	(5)
Evening	Upstream (3)	17	0.25	4.06
	Downstream (3)	69	1	1

\*: Travel Speed Index equals to the upstream speed divided by the downstream speed on the section.

+: Travel Time Index equals to the downstream speed divided by the upstream speed on the section.

The incident (capacity decrease due to the reconstruction of Gulsuyu Interchange) on westbound Highway D100 (E-5) resulted the Travel Speed and Travel Time Indexes at the upstream as 0.25 and 4.06, respectively. This means that while the speed is decreased to 17 km/hr, travel time along the 1700 m long section is increased by 4.06 times at the upstream of the incident location.

**3.2.1.3. Repavement on Northbound Beykoz Shore Road (Minor Arterial)** A lane drop on northbound Beykoz Shore Road caused a significant decrease in travel speed. Speeds observed on the site are given in Table 5.

TABLE 5

Speeds Observed on Northbound Beykoz Shore Road (Minor Arterial)

Time Period	Section (No. of observations)	Ave. Speeds Measured	Travel Speed Index*	Travel Time Index+
(1)	(2)	(km/hr) (3)	(4)	(5)
Noon-peak	Upstream (1)	11	0.26	3.82
	Downstream (2)	42	1	1

\*: Travel Speed Index equals to the upstream speed divided by the downstream speed on the section.

+: Travel Time Index equals to the downstream speed divided by the upstream speed on the section.



The incident (capacity decrease due to lane drop) on northbound Beykoz Shore Road, which is a minor arterial, resulted the Travel Speed and Travel Time Indexes at the upstream as 0.26 and 3.82, respectively. This means while the speed is decreased to 11 km/hr, the travel time is increased by 3.82 times at the upstream of the incident location.

### 3.2.2. Accident Occurrences

**3.2.2.1. Southbound Cekmekoy-Sarigazi Interchange (Minor Arterial)** An accident on southbound Cekmekoy-Sarigazi Interchange resulted a decrease of 76% in travel speed or an increase of 317% in travel time. Speeds observed on the site are given in Table 6.

TABLE 6  
Speeds Observed During Accident on Southbound Cekmekoy-Sarigazi Interchange

Time Period	Section (No. of observations)	Ave. Speeds Measured (km/hr)	Travel Speed Index*	Travel Time Index+
(1)	(2)	(3)	(4)	(5)
Evening	Upstream (4)	18	0.24	4.20
	Downstream (4)	75	1	1

\*: Travel Speed Index equals to the upstream speed divided by the downstream speed on the section.

+: Travel Time Index equals to the downstream speed divided by the upstream speed on the section.

The incident (accident occurrence) on southbound Cekmekoy-Sarigazi Interchange, which is a rural arterial, resulted the Travel Speed and Travel Time Indexes at the upstream as 0.24 and 4.20, respectively. This means while the speed is decreased to 18 km/hr, the travel time is increased by 4.20 times at the upstream of the incident location.

**3.2.2.2. Westbound Minibus (Bagdat) St (Minor Arterial)** An accident on westbound Minibus St (Bagdat St) resulted a decrease of 79.3% in travel speed or an increase of 383% in travel time. Speeds observed on the site are given in Table 7 as follows:

TABLE 7  
Speeds Observed During Accident on Westbound Minibus (Bagdat) St

Time Period	Section (No. of observations)	Ave. Speeds Measured (km/hr)	Travel Speed Index*	Travel Time Index+
(1)	(2)	(3)	(4)	(5)
Evening	Upstream (2)	6	0.21	4.83
	Downstream (4)	29	1	1

\*: Travel Speed Index equals to the upstream speed divided by the downstream speed on the section.

+: Travel Time Index equals to the downstream speed divided by the upstream speed on the section.

The incident (accident occurrence) on westbound Minibus St (Bagdat St), which is a secondary urban arterial, resulted the Travel Speed and Travel Time Indexes at the upstream as 0.21 and 4.83, respectively. This means while the speed is decreased to 6 km/hr, the travel time is increased by 4.83 times at the upstream of the incident location.

**3.2.2.3. Westbound Highway D100 (E-5) at Maltepe Interchange** An accident on westbound Highway D100 (E-5) located 800 m after Maltepe Interchange resulted a decrease of 94.4% in travel speed or an increase of 1680% in travel time. Speeds observed on the site are given in Table 8.



TABLE 8  
Speeds Observed During Accident on Westbound Highway D100 (E-5) 800m After Maltepe Interchange

Time Period	Section (No. of observations)	Ave. Speeds Measured (km/hr)	Travel Speed Index*	Travel Time Index+
(1)	(2)	(3)	(4)	(5)
Evening	Upstream (2)	5	0.056	17.8
	Downstream (2)	89	1	1

\*: Travel Speed Index equals to the upstream speed divided by the downstream speed on the section.

+: Travel Time Index equals to the downstream speed divided by the upstream speed on the section.

The incident (accident occurrence) on westbound Highway D100 (E-5) at Maltepe Intersection resulted the Travel Speed and Travel Time Indexes at the upstream as 0.056 and 17.8, respectively. This means while the speed is decreasing to 5 km/hr, travel time along the 900 m long section is increased by 17.8 times at the upstream of the incident location.

#### 4. SUMMARY AND CONCLUSIONS

This research paper presents the findings of a study investigated the effect of bottlenecks on urban traffic congestion in the city of Istanbul, Turkey. Travel time data collected on- and off-peak times of day using the maximum-car method on major highways and arterials of the city. Bottlenecks are defined as the roadway segments where the number of lanes serving the traffic suddenly decreases and as the toll booths on the access-controlled road segments where vehicles have to slow down (at automated passing, OGS, booths) or come to a complete stop (at cash or magnetic card reader booths). Besides temporary bottlenecks created by incidents such lane drops or shifts due to road or infrastructure constructions and by accident occurrences were also included in this analysis.

Main conclusions from the analysis of travel time data and travel time indexes (TTI) collected during different time periods along major highways and main arterials are as follows:

- The worst travel time values are observed at accident occurrences (TTI is varied between 4.20 and 17.8) since they are unexpected incidents. The worst case was the accident occurrence on Highway D100 (E-5). One of the main reasons for observing such a long delay was the poor “accident management” as well as an illegal act of drivers for using the shoulder as a travel lane. The accident management is generally poor in terms of the arrival of emergency vehicles as well as the police in Istanbul because an average of 642 property damage only (PDO) accidents occur everyday in Istanbul. However, as of April 1st of 2008 drivers involved in a PDO accident do not have to wait for the police to arrive at the accident scene and do the report if they agree upon the occurrence of the accident. This new application was questioned by many with a great suspicion. However, the results after the first month of the application showed that it was accepted by many drivers and the number of cases in which drivers were agreed upon the occurrence of the accident was 66% in Istanbul, %48 in Ankara, and %50 in Izmir, the three biggest cities of Turkey in the order from the largest to the smallest.
- Capacity decreases due to road constructions was also as bad as the road blockages due to accident occurrences (TTI is varied between 3.82 and 4).
- Travel time data as well as the TTI index showed that Bogazici (Bosporus) Bridge was the first choice of commuters to cross the Bosporus since it provides the shorter route compared to Fatih Sultan Mehmet (FSM) Bridge.
- The worst time period to cross the Bosporus over Bogazici Bridge from Europe to Asia side of the city was afternoon off-peak with the TTI between 3.64 and 6.17. From Asia to Europe side, the worst time was morning peak period with the TTI varied between 3.81 and 4.

- While crossing the Bosphorus via FSM Bridge during afternoon peak period, it was seen that heavy vehicles created big troubles that increased the TTI to the highest ever (11.38 and 12.67).
- For weekend trips, travelers always choose Bogazici Bridge over FSM Bridge to cross the Bosphorus.

Remedies for such long delays along major highways and main arterials are as follows:

- For crossing the Bosphorus, more crossing alternatives must be offered to travelers. One less costly one regarding the infrastructure cost is providing more capacity for ferry boat routes.
- Second better as well as more efficient alternative for crossing the Bosphorus is to build a new highway bridge accommodating a high capacity public transportation line.
- For other incidents causing longer delays to urban travelers, one good remedy is doing construction works as fast as possible by working 24 hours a day and doing the maintenance works at nights.

After talking about the magnitude of the delays observed along the highways and main arterials of the city, we will comment on how to handle the solution of corridor improvement without further disturbing the traffic during traffic incidents as follows:

- As a number one action, the poor “accident management” must be replaced by a better one; such as dynamic message signs located at some strategic locations over the major highway network links must convey information on traffic incidents like time of occurrences, duration, speed and travel time conditions upstream of the incidents so that drivers be diverted to alternative routes.
- Such a system can suggest or command alternative routes to drivers if they stuck in traffic due to traffic incidents in order to minimize delays especially along major routes.
- Advanced (by VMS, internet, TV, cellular phones, billboards, etc.) or conventional (by radio) traveler information systems can help drivers beware about the incidents and take actions such as postponing trips, taking alternative modes, and so on.

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# ESTABLISHING AN EFFECTIVE TRAINING MODULE FOR IMDG CODE IN MET INSTITUTIONS

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**Abstract** — *The International Maritime Dangerous Goods (IMDG) Code is a mandatory framework for all aspects of handling dangerous goods and pollutants in maritime transportation. Due to its significance, the IMDG Code has also recommended additional training to seafarers who involve carriage of dangerous goods onboard merchant ships. The main aim of this paper is to design an effective training module towards IMDG Code in Maritime Education and Training (MET) institutions. Moreover, this paper explores the links between shipping casualties associated with dangerous goods and training requirements. The outcomes of this paper contribute IMDG training contents for seafarers and undergraduate/graduate maritime students.*

**Keywords** — *IMDG Code, Maritime transport, Maritime training, MET institutions*

## INTRODUCTION

The transportation of dangerous goods by air, marine, rail, and road is a highly complex issue which requires maintaining safety and environmental related precautions. Besides the enormous numbers of researches on evaluating and controlling the hazards [1-5], the ongoing efforts about developing regulatory framework have continued to ensure safer carriage of dangerous goods using different transportation modes. Furthermore, advance-training requirements on dangerous good transportation are appeared in order to reduce the potential role of relevant operators in casualties. For example, the International Maritime Dangerous Goods (IMDG) Code [6] regulates the all aspects of handling dangerous goods and pollutants in maritime transportation. Principally, it is intended to provide for the safe transportation of hazardous materials by ships, protect operators and to prevent marine pollution. Due to its significance, the IMDG Code has also recommended additional training to seafarers who involve carriage of dangerous goods onboard merchant ships. This paper targets to develop a training module for the IMDG Code to hold in Maritime Education and Training (MET) institutions. It follows the feedbacks from shipping transportation industry to underline the interruptions in carriage of dangerous goods by merchant ships.

## TRANSPORTATION OF DANGEROUS GOOD ONBOARD SHIPS

### Classification of Dangerous Goods

Maritime laws and regulations require using and handling of hazardous goods in respect to the material specifications. For example, one set of requirements may apply to their use in the workplace while different requirements may apply to spill response, sale for consumer use, or transportation. The most widely applied regulatory scheme about the transportation of dangerous goods is so called United Nations Committee of Experts on the Transport of Dangerous Goods (UNCOETDG) issues Model Regulations on the Transportation of Dangerous Goods. In this Model Regulation for all types of transport (sea, air, rail, road and inland waterways) the classification of dangerous goods, by type of risk involved, has been drawn up [7-9]. Most regional and national regulatory schemes for hazardous materials are harmonized to a greater or lesser degree with UN Model Regulation. For instance, the International Civil Aviation Organization has developed regulations for air transport of hazardous materials that are based upon the UN Model but modified to accommodate unique aspects of air transport [7]. Similarly, the International Maritime Organization (IMO) has developed the Dangerous Goods Regulations for transportation on the high seas. Table 1 illustrates the classification of dangerous goods according to IMO Dangerous Goods Regulations which includes formal UNCOETDG's classification.

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TABLE 1  
Classification of Dangerous Goods according to IMO Dangerous Goods Regulations

<b>Class 1</b>	<b>Explosives</b>	
	<b>Division 1.1</b>	Substances and articles which have a mass explosion hazard
	<b>Division 1.2</b>	Substances and articles which have a projection hazard but not a mass explosion hazard
	<b>Division 1.3</b>	Substances and articles which have a fire hazard and either a minor blast hazard or a minor projection hazard or both, but not a mass explosion hazard
	<b>Division 1.4</b>	Substances and articles which present no significant hazard
	<b>Division 1.5</b>	Very insensitive substances which have a mass explosion hazard
	<b>Division 1.6</b>	Extremely insensitive articles which do not have a mass explosion hazard
<b>Class 2</b>	<b>Gases</b>	
	<b>Division 2.1</b>	Flammable gases
	<b>Division 2.2</b>	Non-flammable, non-toxic gases
	<b>Division 2.3</b>	Toxic gases
<b>Class 3</b>	<b>Flammable Liquids</b>	
<b>Class 4</b>	<b>Flammable solids; substances liable to spontaneous combustion; substances which, on contact with water, emit flammable gases</b>	
	<b>Division 4.1</b>	Flammable solids, self-reactive substances and solid desensitized explosives
	<b>Division 4.2</b>	Substances liable to spontaneous combustion
	<b>Division 4.3</b>	Substances which in contact with water emit flammable Gases
<b>Class 5</b>	<b>Oxidizing substances and organic peroxides</b>	
	<b>Division 5.1</b>	Oxidizing substances
	<b>Division 5.2</b>	Organic peroxides
<b>Class 6</b>	<b>Toxic and infectious substances</b>	
	<b>Division 5.1</b>	Toxic substances
	<b>Division 5.1</b>	Infectious substances
<b>Class 7</b>	<b>Radioactive material</b>	
<b>Class 8</b>	<b>Corrosive substances</b>	
<b>Class 9</b>	<b>Miscellaneous dangerous substances and articles*</b>	
<b>MHB</b>	<b>Materials hazardous only in bulk**</b>	

\* Marine pollutants which are not of an otherwise dangerous nature are listed in class 9

\*\* The regulations for materials hazardous only in bulk are not applicable to these materials when they are carried in closed freight containers, however, many precautions may have to be observed

### Links to Shipping Accidents

Shipping accident is a term generally used for any accident results in financial loss, in either life or property or both [11]. The reasons for shipping accidents are many and complex. In addition, several crucial causes play a role in occurrence of shipping accidents. Natural conditions, technical failures, route conditions, ship-related factors, human errors, cargo-related issues are the mostly highlighted factors [10]. Any shipping accident, whatever in nature, is every seafarer's nightmare but the effects of ship accident carry dangerous goods on nature and people is much greater. Usually, any accident might have more than one cause. Nevertheless, investigations and statistical analyses on the basis of the main causal trends explicitly reveal that human errors continue to be the major cause for all shipping accidents. For example, on 14 April 2007, the UK registered product tanker, was carried dangerous good, *Motor Tanker (MT) Audacity* was involved in a collision with the Panama registered general cargo ship *Motor Vessel Leonis*, in very poor visibility, in the precautionary area at the entrance to the *River Humber*. Both vessels sustained damage to their bows. Fortunately there were no injuries and no pollution was occurred [12]. The communication between two ships

involved was unclear and prone to misunderstanding, and the use of standard marine phrases was not practised, the pilots and bridge teams, on both vessels, did not make a full assessment of the risk of collision and VTS procedures for managing traffic in the precautionary area were insufficient are the reasons of this accident [12]. One other accident was occurred on 10 December 2006, chemical and petroleum product tanker, carry clean petroleum product, Prospero was approaching No. 2 Jetty, of the *SemLogistics* terminal, *Milford Haven*, when the master suddenly and without warning lost control of the vessel's podded propulsion system [13]. This caused the vessel to make contact with the jetty's infrastructure, resulting in material damage to both the jetty and the vessel before control was regained. The lack of in-house maintenance procedures, inadequate system knowledge by ship's officers and shore staff, and weak safety management system (SMS) and onboard system documentation, overlaid on a propulsion system for which, when introduced, no dedicated technical standards existed, resulted in a vessel whose resilience to defects and emergencies was significantly weakened are the reasons of this accident. In both two accidents the reasons, especially regarding with the human errors and technical failures based on lack of maintenance [13]. The common viewpoint for prevention of shipping accidents associated with dangerous cargo is to enhance the competency and knowledge of seafarers especially about the key aspects of routine operations (*i.e. cargo handling, tank inspection, gas-freeing, tank cleaning, tank purging, etc.*) in operational level satisfactorily.

## REVIEW OF IMDG CODE REQUIREMENTS

IMDG Code is accepted as an international guide to the transport of dangerous goods by sea and is recommended to governments for adoption or for use as the basis for national regulations. It is intended for use not only by the mariner but also by all those involved in industries and services connected with shipping, and contains advice on terminology, packaging, labeling, placarding, markings, stowage, segregation, handling, and emergency response. The code is updated and maintained by the IMO every 2 years. IMDG Code is divided into seven parts and includes index, appendices, and supplement;

Part 1: General provisions, definitions, training

Part 2: Classification

Part 3: Dangerous good list and limited quantities exceptions

Part 4: Packing and tank provisions

Part 5: Consignment procedures

Part 6: Construction and testing of packagings, IBC, large packagings, portable tanks and road tank vehicles

Part 7: Provisions concerning transport operations

## DESIGN OF IMDG TRAINING MODULE

This section describes a design concept for the IMDG training is held in MET institutions. Training design has enough detail for evaluating training module in the light of criteria established. IMDG training module consists of three levels which are correspondingly explained in the further subsections.

### Level I: Theoretical Aspects

In this level, each trainee attends some courses, which provide familiarity with the general provisions of IMDG Code. This level include a description of the classes of dangerous goods, labeling, marking, packing, stowage, segregation, compatibility provisions and a description of available emergency response applications, precautions and documents and provides an overview of the shipping accidents to identify the contributing factors related to dangerous cargo. The feedback is then used to modify the training module that carry out. In addition, this level gives information about related codes and publications for function-specific training.

### Level II: Rule-based Shipboard Implementations

The successful application of IMDG Code is greatly dependent on the appreciation by all trainees concerned with the risks involved and on a detailed understanding of the regulations. This can be achieved by properly planned and maintained rule-based implementation concerned with the transport of dangerous goods. The main aim of the rule-based implementation is to give detailed training concerning specific dangerous goods transport provisions which are applicable to the function that person performs and to constitute a form

of thinking logical area. At that point in this level, the regulatory basis of IMDG Code is introduced, regulations concerning with transport of dangerous goods are extracted and analyzed and after that try to gain effective problem solving and decision making abilities in limited times to trainees with implement correct rules.

### **Level III: Health and Safety Precautions in Operational Level**

The health and safety precautions in operational level are another aspect within the developed module. In this level, the trainees receive training on emergency response procedures and information and correct using of them, methods and procedures for accident avoidance, such as correct marking, labeling, placarding requirements and appropriate methods of stowage of dangerous goods, general dangers presented by various classes of dangerous goods and immediate procedures to be followed in the event of an unintentional release of dangerous goods including any emergency response procedures for which the person is responsible and personal protection procedures to be followed.

## **CONCLUSION AND DISCUSSIONS**

This research develops a fundamental framework of training module on IMDG Code. It mainly explores the shortfalls in IMDG Code practice in marine transportation to eagerly link up with the proposed training module. Based on the industry based survey of carriage of dangerous goods by ships, the urgent needs for the training of crew members are seemed especially for the following topics: (1) Preparing dangerous goods loading/stowage plan, (2) Load/unload dangerous goods into/from ships, (3) Handle dangerous goods in transport. To satisfy these needs, training modules in three levels are then structured in broad form. The further research proposal can be addressed as the design a detailed syllabus for the developed IDGM training module.

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# AN INVESTMENT DECISION AID PROPOSAL TOWARDS CHOICE OF CONTAINER TERMINAL OPERATING SYSTEMS BASED ON INFORMATION AXIOMS

*Metin CELIK<sup>1</sup>, Selcuk CEBI<sup>2</sup>*

**Abstract** — Choice of an operating system is a critical decision-making process in order to manage optimum layouts for container terminals. The recent marine technology allows utilization of tractor/chassis system, direct straddle carrier system, relay straddle carrier system, yard gantry-crane system, and front-end loader system. This paper proposes a methodology based on information axioms to compare strengths and weakness of terminal operating systems in respect to critical attributes quantitatively. The proposed methodology enables decision aid for both redesigning activities in existing terminals and forthcoming projects of new maritime enterprises.

**Keywords** — Container handling equipment, Container terminal layouts, Information axioms

## TECHNICAL BACKGROUND

Container terminals, the complex investment projects, require great levels of technical infrastructure and equipment [1]. On the other hand, the reliability and efficiency of the operations in container terminals has vital importance to ensure the sustainability of transportation network [2]. The significance of container terminals have been appreciated by the relevant practitioners to maintain the ongoing efforts on optimization of various decision problems such as berth allocation [3], quay crane scheduling [4], yard operations [5], and transfer operations [6]. In modelling of mostly optimization problems [7], the terminal infrastructure and operating system are recognized as common critical constraints. Among these issues, choice of operating systems is a critical decision-making process in order to manage optimum layouts for container terminals.

This paper develops a methodological framework to compare the current terminal operating systems under multiple criteria. It aims to identify the most suitable operating system based on the service requirements of a container terminal. The paper is organized as follows: Section 2 introduces the utilization of information axioms in decision-making. Section 3 states the proposed model and it demonstrates the quantified findings on different operating systems. At the end of the paper, potential contributions of this research in both academic manner and industrial level are discussed.

## RESEARCH METHODOLOGY: DECISION-MAKING USING INFORMATION AXIOMS

An information axiom (IA) is the second axiom of an axiomatic design (AD) proposed by Suh (1990). It establishes a scientific basis to improve design activities based on logical and rational thought process [8]. The primarily goal of an AD approach is to provide reference points to improve design stages [9]. An AD approach uses two axioms named as ‘independence axiom’ and ‘information axiom’. The first axiom states that the independence of functional requirements (FRs) must always be maintained, where FRs are defined as the minimum set of independent requirements that characterizes the design goals [10]. Furthermore, an IA states that the design having the smallest information content is the best design among those designs that satisfy the independence axiom [9]. At this insight, an IA is recognized as a conventional method, which facilitates the selection of proper alternative that has minimum information content. Recently, the IA has been adapted to solve different multiple criteria decision-making problem cases in literature [11-18].

The theoretical concept of an IA deals with minimizing the information content ( $I$ ) of the design. It targets to reach minimum value of  $I$  which is the best design alternative among the feasible solutions that satisfy the independence axiom. In IA application, a multiple criteria selection process, which states an alternative has the highest probability of FR success, it is so-called as the best design [10]. Apart from the traditional applications of an IA, this paper follows an ideal FR (IFR) [19] to rank the terminal operating systems.

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The mathematical background of an IA approach can be introduced as follows: If the probability of success for given FR is  $p$ , the  $I$  is calculated using Eq.1:

$$I_i = \log_2 \frac{1}{p_i} \quad (1)$$

If there is more than one FR, the  $I$  is calculated as follows:

$$I_{system} = -\log_2 P_{(m)} \quad (2)$$

$$I_{system} = -\log_2 \left( \prod_{i=1}^m P_i \right) \quad (3)$$

$$I_{system} = -\sum_{i=1}^m \log_2 P_i = \sum_{i=1}^m \log_2 (1/P_i) \quad (4)$$

This paper developed an investment decision aid approach to assist the relevant maritime enterprises in terminal operating system choice. The proposed decision aid system also involves a group aggregation, which is also accomplished using a Borda score method. It gives consistent ranking of terminal operating system alternatives. The proposed decision aid towards choice of terminal operating system in accordance with the expectations of maritime enterprises is given in Figure 1.

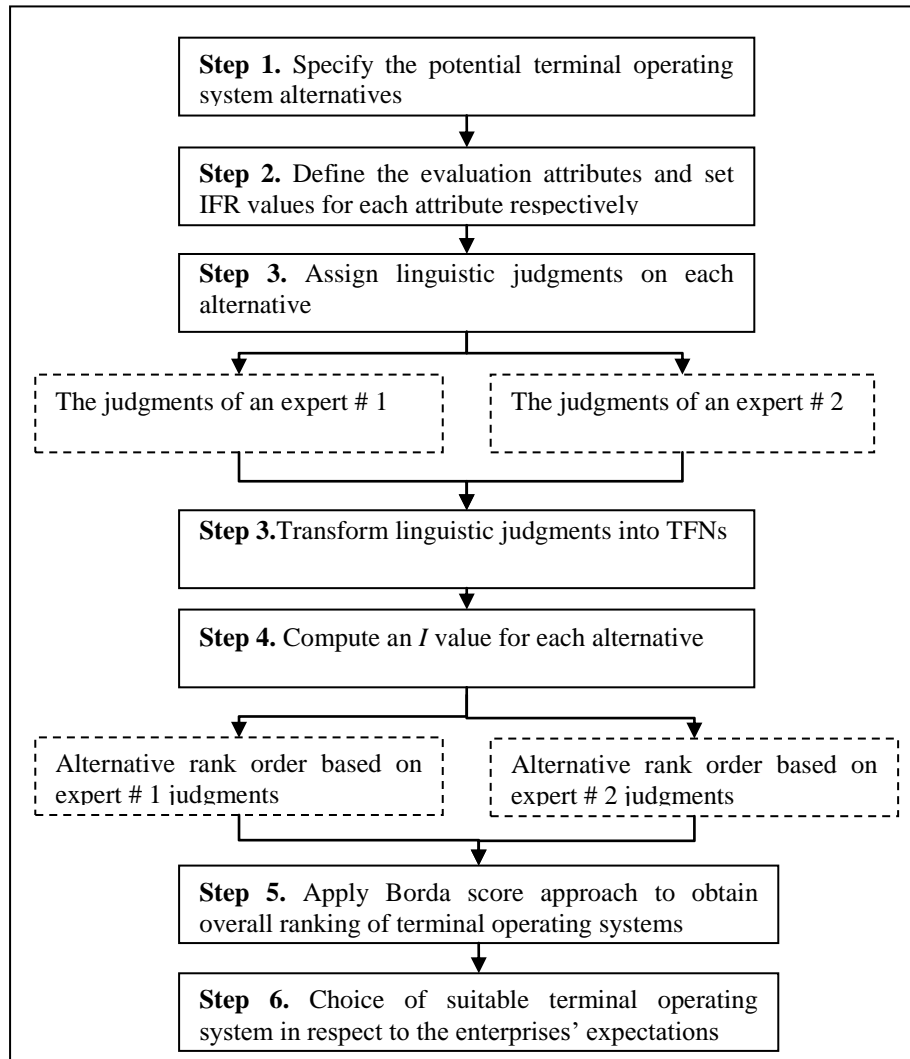


FIGURE 1

Proposed investment decision aid for container terminals



## DEMONSTRATION OF PROPOSED MODEL

This paper follows the research methodology based on fuzzy information axioms to model the operating system selection problem for container terminals.

### Problem Statement

The container handling system selection problem is particularly addressed in literature [20]. In this paper, it is determined to compare the similar alternatives. Therefore, the proposed model incorporates the five different container terminal operating systems as follows:

- (A<sub>1</sub>) Tractor/chassis system
- (A<sub>2</sub>) Straddle carrier direct system
- (A<sub>3</sub>) Straddle carrier relay system
- (A<sub>4</sub>) Yard gantry system
- (A<sub>5</sub>) Front-end loader system

On the other hand, the alternatives are compared based on following critical attributes: advantages in land utilization ( $b_1$ ), automation potential ( $b_2$ ), safety and reliability in cargo handling operations ( $b_3$ ), capital cost ( $c_1$ ), operating and maintenance cost ( $c_2$ ), manning level ( $c_3$ ).

### Assigning Fuzzy Linguistic Judgments on FRs & Alternatives

The decision-making methodology with information axioms requires assigning of judgements about expectations from alternative operating systems in terms of identifying the IFR values. The linguistic scale and corresponding TFNs are given in Table 1.

TABLE 1  
Linguistic scale

Linguistic Term	Abbreviation	TFN
Very Low	VL	(0.0,0.0,0.3)
Low	L	(0.0,0.3,0.5)
Medium	M	(0.3,0.5,0.7)
High	H	(0.5,0.7,1.0)
Very High	VH	(0.7,1.0,1.0)

Considering the evaluation attributes, Table 2 illustrates the IFR values in TFNs form. These judgements represent the expectations of an enterprise from container terminal operating systems. Hereby, to demonstrate the proposed decision aid, the IFR values are randomly assigned. Those values can be modified in respect to the different projections of maritime enterprises.

TABLE 2  
Definitions of IFR values on attributes in TFNs form

Evaluation attributes	Cost/Benefit	Functional requirements	
		Linguistic terms	TFNs
Advantages in land utilization ( $b_1$ )	Benefit	At least "H"	At least (0.5,1.0,1.0)
Automation potential ( $b_2$ )	Benefit	At least "M"	At least (0.3,1.0,1.0)
Safety and reliability in cargo handling operations ( $b_3$ )	Benefit	At least "H"	At least (0.5,1.0,1.0)
Capital cost ( $c_1$ )	Cost	At most "M"	At most (0.0,0.0,0.7)
Operating and maintenance cost ( $c_2$ )	Cost	At most "M"	At most (0.0,0.0,0.7)
Manning level ( $c_3$ )	Cost	At most "M"	At most (0.0,0.0,0.7)

Furthermore, the judgements of the two different experts on alternative operating systems are given in Table 3 and Table 4. In this research, the expert profile mainly consists of professional managers from private container ports in Turkish maritime industry.

TABLE 3  
Judgements of Expert #1 on alternative operating systems

Alternatives	Evaluation attributes					
	b <sub>1</sub>	b <sub>2</sub>	b <sub>3</sub>	c <sub>1</sub>	c <sub>2</sub>	c <sub>3</sub>
(A <sub>1</sub> ) Tractor/chassis system	M	L	H	L	VL	VL
(A <sub>2</sub> ) Straddle carrier direct system	H	H	H	H	H	M
(A <sub>3</sub> ) Straddle carrier relay system	M	M	H	M	M	L
(A <sub>4</sub> ) Yard gantry system	VH	H	H	H	H	H
(A <sub>5</sub> ) Front-end loader system	VH	H	H	H	H	H

TABLE 4  
Judgements of Expert #2 on alternative operating systems

Alternatives	Evaluation attributes					
	b <sub>1</sub>	b <sub>2</sub>	b <sub>3</sub>	c <sub>1</sub>	c <sub>2</sub>	c <sub>3</sub>
(A <sub>1</sub> ) Tractor/chassis system	M	M	H	L	L	VL
(A <sub>2</sub> ) Straddle carrier direct system	M	VH	M	H	M	M
(A <sub>3</sub> ) Straddle carrier relay system	M	VH	M	H	M	M
(A <sub>4</sub> ) Yard gantry system	VH	VH	VH	H	H	M
(A <sub>5</sub> ) Front-end loader system	H	H	M	M	M	M

### Findings

The information content values are computed based on decision-making algorithm with fuzzy information axioms. To illustrate this algorithm, a sample calculation is provided for judgements of Expert #2 on straddle carrier direct system (A<sub>2</sub>) with respect to advantages in land utilization (b<sub>1</sub>) as follows:

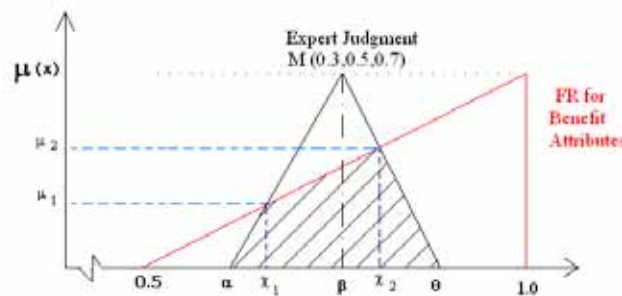


FIGURE 1.

Judgements of Expert #1 for straddle carrier direct system with respect to land utilization (b<sub>1</sub>)

$$I_i = \log_2 \frac{1}{p_i}$$

$$I_{11} = \log_2 \frac{\theta - \alpha}{(x_2 - x_1 + \theta - \alpha)\mu_1 + (\mu_1 - \mu_2)(x_2 - x_1)} = 0.678$$

Finally, Table 4 and 5 represents the total  $I$  values for each alternative operating system with respect to the assessments of experts. According to the findings, the rankings of the alternatives are as follow;  $A_1 > A_3 > A_2$   $A_4 = A_5$  for Expert # 1,  $A_5 > A_1 > A_4 > A_3 > A_2$  for Expert # 2 and  $A_1 > A_5 > A_3 > A_4 > A_2$  with respect to Borda function. There is a slight difference between the ranking orders of each expert. If we use the additive procedure for the total IA values the rank also is found as  $A_1 > A_5 > A_3 > A_4 > A_2$ . Since the ultimate goal of the decision aid is to offer an operating system for container terminal, *Tractor-trailer system* is considered as the most feasible operating system alternative for this enterprise. However, the rank reversals can be possible if the preferences of maritime enterprises are changed in terms of modifying the IFR values.

TABLE 4  
Calculated information content values on alternative operating systems according to Expert 1

Alternatives	Information contents						
	b <sub>1</sub>	b <sub>2</sub>	b <sub>3</sub>	c <sub>1</sub>	c <sub>2</sub>	c <sub>3</sub>	Total
(A1) Tractor-trailer system	2.809	3.491	0.678	0.286	0	0	7.264
(A2) Straddle carrier direct system	0.678	0.286	0.678	3.491	3.491	1.169	9.793
(A3) Straddle carrier relay system	2.809	1.169	0.678	1.169	1.169	0.286	7.28
(A4) Yard gantry system	0	0.286	0.678	3.491	3.491	3.491	11.44
(A5) Front-end loader system	0	0.286	0.678	3.491	3.491	3.491	11.44

TABLE 5  
Calculated information content values on alternative operating systems according to Expert 2

Alternatives	Information contents						
	b <sub>1</sub>	b <sub>2</sub>	b <sub>3</sub>	c <sub>1</sub>	c <sub>2</sub>	c <sub>3</sub>	Total
(A1) Tractor-trailer system	2.809	1.184	0.678	0.286	0.286	0	5.243
(A2) Straddle carrier direct system	2.809	0	2.809	3.491	1.169	1.169	11.45
(A3) Straddle carrier relay system	2.809	0	2.809	3.491	1.169	1.169	11.45
(A4) Yard gantry system	0	0	0	3.491	3.491	1.169	8.151
(A5) Front-end loader system	0.678	0.286	0.678	1.169	1.169	1.169	5.149

## CONCLUSION AND DISCUSSIONS

This paper developed an investment decision aid towards a techno-commercial problem on container terminal operating system selection. The advantage of the proposed methodology based on IA is seemed especially definition of IFR values to express the expectations and preferences of an enterprise from terminal operating systems. Therefore, utilization of this approach ensures a great flexibility to relevant decision makers in order to choice an adequate operating system in respect to the strategic and operational priorities of maritime enterprises in container terminal investment projects. The changes in IFR preferences can slightly influence the ranks of alternative operating systems. Hence, the proposed decision aid ensures consistent solutions for the different projections belong to enterprises in maritime sector. The model outcomes also aid to redesign activities of current operating systems in order to create a combined operating system in container terminals.

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# **Chapter 6**

Evaluation of Public Policies, Network Models and Environment



# POSSIBILISTIC LINEAR PROGRAMMING APPROACH FOR STRATEGIC RESOURCE PLANNING

Özgür KABAK<sup>1</sup>, Füsün ÜLENGİN<sup>2</sup>

**Abstract** — Strategic resource planning decisions are very important for the medium and long term planning success of manufacturing companies. The inputs of the resource planning models face environmental and system uncertainties. In this paper, a fuzzy logic- based modeling is proposed to deal with those uncertainties. For this purpose, a possibilistic linear programming (PLP) model is used to make strategic resource planning decisions using fuzzy demand forecasts as well as other inputs such as costs, yield rates etc. The objective of proposed PLP is to maximize the total profit of the enterprise. The model is designed to guide the supply chain managers to decide on strategic problems such as “which resources are used for which product”, “which resources are outsourced”, “which products should be produced/outsourced and how much”, and “demand of which markets are satisfied and how much”. The model is finally applied to Mercedes-Benz Turk, one of the largest bus manufacturing companies in the world, and the results are evaluated.

**Keywords** — Fuzzy modeling, Possibilistic linear programming, Supply chain planning, Uncertainty.

## INTRODUCTION

The interest in supply chain planning (SCP) has recently increased due to the fact that the opportunity of an integrated planning of the supply chain (SC) can improve the profitability, reduce production and outsourcing costs and enhance customer service levels. As a result, the enterprises can cope with increasing competitiveness introduced by the market globalization [1][2]. Based on the detailed analysis of the papers in Science Direct database for the 2004-2008 period, the applied papers or mixed (applied and theoretical) papers are less than the theoretical papers. Similarly, the studies dealing with two-tier SCs are higher in number rather than the ones that models multi-tier, serial, and network SCs. However, the use of network structure simplifies the representation of SC units and/or functions as well as the interrelationships among them. Consequently, the network structures could be easily transformed to mathematical models. This property is important for the improvement of a SC system (e.g. [3][4]) as well as for taking the operational and strategic decisions (e.g. [5][6]) or designing a new product (e.g. [7][8]). The network based models developed so far have several drawbacks, the most important of which is their deterministic nature. However, in SCP models there are several uncertainties that should be taken into account. Especially in specific problems that necessitate future projections such as new product design or strategic planning, there will be several parameters that cannot be estimated deterministically. Therefore, the fuzzy logic is an important tool to model those types of uncertainties. There are several SC models that assume fuzzy parameters such as demand (e.g. [9][10][11][12][13][14][15]), operation time (e.g. [11]), price (e.g. [14]). In the fuzzy models, generally, the objective function coefficients (see [16][12][17][15]), the constraint parameters (see [18][17][15]), the satisfaction of the objective function (see [19][20][21]), and the satisfaction of constraints (see [19][21]) are modeled with fuzzy modeling. In the majority of the fuzzy logic-based SC models, all the possible uncertainties are not taken into account. For example Hsu and Wang [16] consider only demand as uncertain. Mula et al. [19] treat the realization of the constraint as fuzzy but do not model the fuzziness of the objective function and of the constraint parameters. Another problem encountered in fuzzy logic based models is identified in the defuzzification process. In several researches the defuzzification of the fuzzy parameters is made at the very beginning of the solution (e.g. [14][21]). Although such an approach facilitates the solution, it cannot properly reflect the fuzziness of the results. In the network-based SC models developed so far, another drawback is the assumption of centralized decision (e.g. [4][5]). In fact a centralized approach may provide an efficient approach for a system-wide improvement. However, in real life situation the firms in the SC may not accept such a centralized approach and may prefer a system where their own decisions will also play an important role [22]. Thus, an efficient SC should allow the possibility of considering the decisions at the different levels of the hierarchy in the SC. Additionally the network-based models encountered in the literature are generally very difficult to apply to a real life cases (e.g. [3][4][8][6][23]). Although some

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heuristics are proposed to solve the models, generally, there have no guarantee of optimum solution (see [10][11][18][12][17][24][21]). In those papers, generally small hypothetical examples are used to show the applicability of the models and the possibility of their application to large scale problems is not discussed.

According to these results it can be concluded that a model that is network-based and that treats the SC as a system of interrelated functions, includes as many efficient members of different hierarchy levels as possible and uses the fuzzy logic to reflect the fuzziness of the planning decision will be an important improvement in the related research area. Additionally the solution approach of the proposed model should be easily applied to large scale real life cases. For this purposes a possibilistic linear programming approach is proposed to model the SC in strategic resource planning perspective. In the following section the proposed model is given.

## PROPOSED MODEL

The main idea of the proposed model is to allow uncertain and therefore flexible decisions to cope with the uncertainties revealed in strategic SCP. In SCP problems, demand has been the most important and extensively studied source of uncertainty (e.g. [1][25][26][21][27][16][12]). Given the fact that effectively meeting customer demand is what mainly drives most SCP initiatives, it is appropriate to put emphasis on incorporating demand uncertainty in the planning decisions. Under this uncertain environment to attempt to make crisp decisions may cause irrelevant or irreversible long term decisions that will need important revisions in medium or short term. Therefore fuzzy decisions are suggested for strategic SCP planning in the proposed model. In order to make fuzzy decision in SCP; a PLP is utilized. In fuzzy linear programming problems, the coefficients of decision variables are fuzzy numbers while decision variables are crisp ones. On the other hand, in PLP formulation the coefficients of decision variables are crisp and/or fuzzy numbers while decision variables are obtained as fuzzy numbers [28].

The problem examined in the paper is motivated from Lakhal et al. [3]. The model accepts that the below given configuration is given at the beginning of the model development. (1) A SC that is the integration of the focal enterprise, its current suppliers and customers, as well as the potential suppliers and customers, and related products, semi-products and raw materials (in the rest of the paper “product” will be used for these three concepts), (2) Resources used to produce the products as well as their costs and capacity levels, (3) Outsourced products and other outsourcing opportunities, as well as their costs, (4) Production and outsourcing yield rates of products. Based on the given data, the proposed model helps the enterprise make decisions about the following strategic questions: 1) Which product should be produced internally? 2) Which resources should be utilized to the production of which product? 3) Which products should be outsourced, and how much? 4) Demands of which market should be satisfied? Additionally, the model can be used to predict the changes of decisions on the change of different input values based on what-if analysis.

### The Proposed Possibilistic Linear Programming Model

The decisions that are sought to made in the proposed model are the production ( $\tilde{U}_p$ ), outsourcing ( $\tilde{D}_p$ ) and sales amounts ( $\tilde{S}_p$ ) of the products as well as the outsourcing amount of the resources ( $\tilde{D}K_r$ ) where  $p$  and  $r$  represent products and resources, respectively ( $p \in P, r \in R$ ). In order to deal with the uncertainties in SCP all of the decision variables are designed to be fuzzy and it is represented by the sign of ( $\sim$ ) over their symbols.

All the products and the resources can be outsourced theoretically. However in the real problems, firms may limit the outsourcing and production decisions of some products or resources. For his purpose the set of products that should be outsourced are labeled as PD, and the set of products that should be produced are labeled as PU and the following constraints are included into the model:

$$\tilde{U}_p \leq 0, \quad \forall p \in PD \quad (1)$$

$$\tilde{D}_p \leq 0, \quad \forall p \in PU \quad (2)$$

Outsourcing amounts of the products may be limited based on the capacity of the suppliers or according to a strategic decision of the firm. The following constraint is added to the model to introduce the capacity limit.

$$\tilde{D}_p \lesssim DC_p, \quad \forall p \quad (3)$$

Where  $DC_p$  is the capacity limit related to product  $p$  and  $\lesssim$  is the fuzzy less than sign.

In the proposed model system uncertainty is represented by “yield rates”. For the production uncertainty, production yield rate ( $\tilde{V}U_p$ ) is used that is the ratio between actual and planned production amounts. Similarly, outsourcing yield rate ( $\tilde{V}D_p$ ) is proposed for outsourcing uncertainty.



For each product, total amount of production and outsourcing should be greater than the sum of amount of the product used for the other products and sold amount of the product. The following constraint is offered to guarantee this inequality that also includes the yield rates:

$$\tilde{V}U_p \otimes \tilde{U}_p \oplus \tilde{V}D_p \otimes \tilde{D}_p \gtrsim \sum_u (BOM_{pu} \otimes \tilde{U}_u) \oplus \tilde{S}_p \quad \forall p \in P \quad (4)$$

Where  $BOM_{pu}$  is the bill of materials that represents the amount of product  $p$  required to produce product  $u$ .  $\oplus, \otimes, \gtrsim$  are fuzzy summation, fuzzy multiplication, and fuzzy greater than signs, respectively.

In the model, the production amount is constrained to the resources. During the production of a product some resources are consumed. All the resources including machine times, labor times, transportation and warehousing resources that are used in the production process should be included in the model.  $KK_{pr}$  represents the amount of resource  $r$  used to produce product  $p$ . The company has capacity for the resources that can be increased by rent and outsourcing. Outsourcing is also constrained to the capacity of the suppliers.  $KC_r$  is the capacity of resource  $r$ .  $DKC_r$  is the outsourcing capacity. The following constraints are introduced to relate production and resources and the capacities.

$$\sum_p (\tilde{U}_p \otimes KK_{pr}) \gtrsim KC_r \oplus \tilde{D}K_r, \quad \forall r \quad (5)$$

$$\tilde{D}K_r \gtrsim DKC_r, \quad \forall r \quad (6)$$

The main source of uncertainty in SCP is the demands. For this reason the demands related to product  $p$  are represented by fuzzy numbers:  $\tilde{T}_p$ .

There are two ways to model network structured systems in mathematical programming: (1) maximization of the profit, (2) minimization of the cost. The last echelon of the network is limited to some value in the former model while the last echelon is greater than some value in the latter. In the proposed model profit maximization is the objective; therefore the sales amounts are limited to the demands.

$$\tilde{S}_p \gtrsim \tilde{T}_p, \quad \forall p \in P \quad (7)$$

Revenues and costs should be defined to find the profit. Total sales revenue of the firm is calculated as follows, where  $F_p$  is the sales price of the product  $p$ .

$$Revenue = \sum_{p \in P} (\tilde{S}_p \otimes F_p) \quad (8)$$

Total cost is composed of product outsourcing cost, source consuming cost, and source outsourcing cost which are calculated as given in the following:

$$Product\ outsourcing\ cost = \sum_{p \in P} (DM_p \otimes \tilde{D}_p) \quad (9)$$

$$Source\ consuming\ cost = \sum_{r \in R} \left( KM_r \otimes \sum_{p \in P} (\tilde{U}_p \otimes KK_{pr}) \right) \quad (10)$$

$$Source\ outsourcing\ additional\ cost = \sum_{r \in R} (\tilde{D}K_r \otimes DKM_r) \quad (11)$$

Where  $DM_p$  is the unit outsourcing cost of product  $p$ ,  $KM_r$  is the unit consuming cost of source  $r$ , and  $DKM_r$  is the additional cost of outsourcing source  $r$ .

As a result the basic objective of the model ( $Z_1$ ) is constructed as follows:

$$\max Z_1 \cong \sum_{p \in P} (\tilde{S}_p \otimes F_p) (-) \left( \sum_{r \in R} \left( KM_r \otimes \sum_{p \in P} (\tilde{U}_p \otimes KK_{pr}) \right) \oplus (\tilde{D}K_r \otimes DKM_r) \right) \oplus \sum_{p \in P} (DM_p \otimes \tilde{D}_p) \quad (12)$$

All decision variables of the model are fuzzy numbers. If the profit maximization is designed to be the only objective then the fuzziness of decision variables as well as the objective function can not be controlled and the results of the model may be inapplicable. For this reason an additional objective is defined to minimize the fuzziness of the profit. Controlling the fuzziness in the profit is also controls the fuzziness in the decision variables as the profit is composed of the decision variables. The concept of entropy is used to measure the fuzziness of the fuzzy sets and numbers. The objective of the fuzziness of profit ( $Z_2$ ) is defined as follows where  $H(\tilde{A})$  indicates the entropy of fuzzy number  $\tilde{A}$ .

$$\min Z_2 = H(Z_1) \quad (13)$$

As a result a multi-objective possibilistic linear programming model is obtained. Details of the solution procedure of this model are given in the following section.

### Solution of the proposed PLP model

There are different approaches to solve PLP problems. Buckley and Feuring [30] suggested an evolutionary algorithm to solve the fuzzy flexible program that is used to explore the whole nondominated set to the multi-objective fuzzy linear program where all coefficients and decision variables are fuzzy. Tanaka et al. [28] proposed transformations of fuzzy constraints characterized as interval, triangular, and exponential possibility distributions to linear constraints according to predetermined possibility levels. Disadvantage of the former is complex solution procedure while the latter needs predetermined possibility levels.

In this model, triangular fuzzy numbers (TFNs) are chosen to represent all fuzzy parameters and variables since TFNs are enough to represent the uncertainty in demands and yield rates as well as the decision variables and it is easy to apply mathematical operations for TFNs. A TFN,  $\tilde{A}$ , is defined by its left support (L), medium value (M), and right support (R). In the solution procedure, normalization of the multiple objectives is suggested to aggregate them in the same scale. In order to normalize the fuzzy objectives the upper and lower bounds of objective values are found. Initially the following LP model is suggested to find the upper and lower bounds of the profit.

(LP-1) (definitions of the parameters and decision variables are introduced in Table 1)

*Objective function*

$$\text{Max } Z = \sum_p (S'_p * F_p) - \left( \sum_r \left( KM_r * \sum_p (U'_p * KK_{pr}) + (DK'_r * DKM_r) \right) + \sum_p (DM_p + D'_p) \right) \quad (14)$$

*Subject to*

$$U'_p \leq 0, \quad p \in \text{PD} \quad (15)$$

$$D'_p \leq 0, \quad p \in \text{PU} \quad (16)$$

$$D'_p \leq DK_p, \quad \forall p \quad (17)$$

$$VU'_p * U'_p + VD'_p * D'_p \geq \sum_u (BOM_{pu} * U'_u) + S'_p, \quad \forall p. \quad (18)$$

$$\sum_p (U'_p * KK_{pr}) \leq KC_r + DK'_r, \quad \forall r \quad (19)$$

$$DK'_r \leq DKC_r, \quad \forall r \quad (20)$$

$$S'_p \leq T'_p, \quad \forall p \quad (21)$$

$$U'_p, D'_p, S'_p \geq 0, \quad \forall p \quad (22)$$

All decision variables and the constraints in LP-1 are defined by crisp numbers. The objective function of LP1, which is defined in (14), is the defuzzified version of the first objective in PLP. The defuzzification of the fuzzy parameters in PLP while converting it to LP-1 is realized according to the result that is aimed to be reached. For instance the yield rates and the demands are considered to be at their highest level (i.e. right supports of the corresponding TFNs) to find the upper bound of the profit while they are considered to be at their lowest level (i.e. left supports of the corresponding TFNs) to reach the lower bound of the profit. When the upper bound ( $\bar{Z}_1$ ) and lower bound ( $\underline{Z}_1$ ) of the profit is calculated by running the LP-1 twice with different parameters, the normalization of the first objective of the PLP is made according to the following formula:

$$\frac{Z_1^M - \underline{Z}_1}{\bar{Z}_1 - \underline{Z}_1} \quad (23)$$

Where  $Z_1^M$  is the medium value of the profit, which is obtained as a TFN. On the other hand, the following formula is used to normalize the second objective of the PLP:

$$\frac{(\bar{Z}_1 - \underline{Z}_1) - (Z_1^R - Z_1^L)}{\bar{Z}_1 - \underline{Z}_1} \quad (24)$$

Where  $Z_1^R$  and  $Z_1^L$  are the right and left supports of the profit. Here, the entropy of a TFN is calculated by the difference of the two supports.

When the normalization formulas for the objectives are defined, the PLP model can be converted to LP-2.

TABLE 1  
Definitions of the parameters and the decision variables in LP 1 and LP 2

<i>Indices:</i>			
$p, u$	Products; $p, u \in P$	$R$	Resources; $r \in R$
$i$	Critical points of TFN, $i = L, M, R$		
<i>Parameters:</i>			
$P$	The set of products	$R$	The set of resources
$PD$	The set of products that should be outsourced, $PD \subset P$	$PU$	The set of products that should be produced, $PU \subset P$
$BOM_{pu}$	Bill of materials matrix (amount of product $p$ that is required for product $u$ )	$KK_{pr}$	Amount of resource $r$ that is required for product $p$
$KC_r$	The capacity of resource $r$	$KM_r$	Unit cost of resource $r$
$DKC_r$	Outsource capacity of resource $r$	$DKM_r$	Unit outsourcing cost of resource $r$
$DM_p$	Unit additional cost of outsourcing product $p$	$DK_p$	Capacity of outsourcing amount of product $p$
$T'_p$	Demand of product $p$	$F_p$	Price of product $p$
$VU'_p$	Production yield rate of product $p$	$VD'_p$	Outsourcing yield rate of product $p$
$VD^i_p$	$i^{th}$ critical point of outsourcing yield rate of product $p$	$VU^i_p$	$i^{th}$ critical point of production yield rate of product $p$
$T^i_p$	$i^{th}$ critical point of demand of product $p$	$\bar{Z}_1, \underline{Z}_1$	Upper and Lower bounds of the profit
<i>Decision Variables:</i>			
$U'_p$	Production amount of product $p$	$D'_p$	Outsourcing amount of product $p$
$S'_p$	Sales amount of product $p$	$DK'_r$	Outsourcing amount of resource $r$
$U^i_p$	$i^{th}$ critical point of production amount of product $p$	$D^i_p$	$i^{th}$ critical point of outsourcing amount of product $p$
$S^i_p$	$i^{th}$ critical point of sales amount of product $p$	$DK^i_r$	$i^{th}$ critical point of outsourcing amount of resource $r$
$Z^i_1$	$i^{th}$ critical point of profit	$\lambda$	Minimum level of the the normalized objectives
The signed ( $X'$ ) parameters and decision variables are defuzzified versions of the similar variables of PLP model.			

(LP-2) (definitions of the parameters and decision variables are introduced in Table 1)

*Objective Function*

$$\text{Max } Z = \lambda \quad (25)$$

*Subject to;*

$$\lambda \leq (Z_1^M - \underline{Z}_1) / (\bar{Z}_1 - \underline{Z}_1) \quad (26)$$

$$\lambda \leq ((\bar{Z}_1 - \underline{Z}_1) - (Z_1^R - Z_1^L)) / (\bar{Z}_1 - \underline{Z}_1) \quad (27)$$

$$Z_1^M = \left( \sum_p (S_p^M * F_p) - \left( \sum_r \left( KM_r * \sum_p (U_p^M * KK_{pr}) + (DK_r^M * DKM_r) \right) + \sum_p (DM_p * D_p^M) \right) \right) \quad (28)$$

$$Z_1^L = \sum_p (S_p^L * F_p) - \left( \sum_r \left( KM_r * \sum_p (U_p^R * KK_{pr}) + (DK_r^R * DKM_r) \right) + \sum_p (DM_p * D_p^R) \right) \quad (29)$$

$$Z_1^R = \sum_p (S_p^R * F_p) - \left( \sum_r \left( KM_r * \sum_p (U_p^L * KK_{pr}) + (DK_r^L * DKM_r) \right) + \sum_p (DM_p * D_p^L) \right) \quad (30)$$

$$U_p^R \leq 0, \quad p \in PD \quad (31)$$

$$D_p^R \leq 0, \quad p \in PU \quad (32)$$

$$D_p^R \leq DC_p, \quad \forall p \quad (33)$$

$$VU_p^i * U_p^i + VD_p^i * D_p^i \geq \sum_u (BOM_{pu} * U_p^i) + S_p^i, \forall (p, i) \quad (34)$$

$$\sum_p (U_p^i * KK_{pr}) \leq KC_r + DK_r^i, \quad \forall (r, i) \quad (35)$$

$$DK_r^R \leq DKC_r, \quad \forall r \quad (36)$$

$$S_p^i \leq T_p^i, \quad \forall(p,i) \quad (37)$$

$$U_p^L \leq U_p^M \leq U_p^R, \quad \forall p \quad (38)$$

$$D_p^L \leq D_p^M \leq D_p^R, \quad \forall p \quad (39)$$

$$S_p^L \leq S_p^M \leq S_p^R, \quad \forall p \quad (40)$$

$$DK_r^L \leq DK_r^M \leq DK_r^R, \quad \forall r \quad (41)$$

$$U_{pi}, D_{pi}, S_{pi} \geq 0, \quad \forall(p,i) \quad (42)$$

The aim of LP-2 is to maximize the minimum level of normalized objectives (defined as  $\lambda$ ) of PLP.  $\lambda$  is obtained through (26) and (27) while three critical values of the profit is calculated by using (28)-(30). The constraints (31)-(37) are the conjugate of (1)-(7) after the application of TFN operations. Constraints (38)-(41) prevents having illogical TFNs for decision variables (for TFN,  $\tilde{A}(L, M, U)$ ,  $L \leq M \leq U$  should be satisfied). In (42) sign restrictions are given.

## APPLICATION IN AUTOMOTIVE INDUSTRY

Mercedes-Benz Türk A.Ş. owns one of world leading bus manufacturing plants located in Hoşdere, İstanbul, Turkey. It produces several types of buses with capacity of 4000 per year.

The proposed methodology is applied in the body manufacturing of the plant. Particularly, it is used to make strategic resource planning of the year 2009 for one kind of body, coded as “Integro 15/R”, which is sold to Mercedes, Germany. The body is composed of 2178 product, sub-product and raw materials, 823 of which are raw materials. There are two main groups of raw materials, which are metal tubes and metal sheets.

While applying the proposed model to the body production, first of all, the resources are determined. The main resource of the production is labor. On the other hand, there are numerous different kinds of work benches and work stations in the production process. It could be very difficult to model the system by including all different benches/stations since some of them are substitutes of each other, processing times are not clear etc. Therefore main sections of the production process are considered as the resources of the system. The production process is composed of three sections: tube processing, sheet processing and welding. The related parameters about the resources are given in Table 2.

TABLE 2  
Parameters related to resources

Resource ID	The Resource	Capacity (Year 2009)	Unit cost (€)	Outsourcing capacity	Additional unit cost of outsourcing (€)
1	Labor	4422600 man-hours	0,216670	2063880 man-hours	0,1083300
2	Tube processing	762048 hours	0,022159	76205 hours	0,0110795
3	Sheet processing	394632 hours	0,080577	39463 hours	0,0402885
4	Welding	3129840 hours	0,004029	312984 hours	0,0020145

One of the important inputs of the model is production yield rates. Yields occur in the production system according to products' production process. The yield rates are specified for the product groups (see Table 3).

TABLE 3  
Production yield rates

Product group	Pessimistic value of the yield rate	Most possible value of the yield rate	Optimistic value of the yield rate
Products of tube process	0.988	0.992	0.995
Products of sheet process	0.982	0.988	0.993
Products of welding	0.976	0.984	0.990
Other products	0.994	0.996	0.997

Yield rates related to outsourced products are specified according to the type of the raw material as given in Table 4. The demands of the body is specified thorough aggregating several statistical and judgmental forecasts as  $T_1 = (180, 202.8, 225.6)$ .

In order to solve the proposed PLP that is structured according to the given parameters, first of all, upper and lower bounds of the profit are calculated with LP-1. For the upper bound of the profit the optimistic values of the fuzzy parameters are taken into consideration while pessimistic values are considered for the

lower bound. As a results of two runs of LP-1, it is found that  $\bar{Z}_1 = 788024$  and  $Z_1 = 565761$ , which indicates that the maximum fuzziness level of the profit is 222263. Then LP-2 is employed to reach the final solution.

TABLE 4  
Outsourcing yield rates

Product group	Pessimistic value of the yield rate	Most possible value of the yield rate	Optimistic value of the yield rate
Metal Tubes	0.993	0.997	1.000
Metal sheets	0.990	0.995	1.000
Other raw materials	0.995	0.998	1.000

LP-2 is solved in GAMS software with CPLEX solver. According to the results, the profit, which is specified as a TFN, is (527968, 654528, 661464). This result indicates that the most probable value of the profit is €654538 while the pessimistic and optimistic profits are equal to 527968 and 654528, respectively.  $\lambda$  and the normalized values of the objectives are equal to 0.399. The sales amount of the body “Integro 15/R” is (177.600, 186.037, 186.037). The results show that the capacities of the resources are adequate for determined production level. According to most possible values of the production, 86.27% of the labor, 99.94% of the tube processing, 92.86% of the sheet processing, and 81.12% of the welding sources are utilized. Results related to production/outsourcing amounts indicate that there is no uncertainty in the outsourcing amounts (i.e. the three critical values of the related TFNs are equal). On the other hand, production amounts of the 66% of the products are uncertain where the level of uncertainty varies from %0 to %12.

## CONCLUSIONS

In this paper a possibilistic linear programming model is proposed to make strategic resource planning decisions in SC context. The proposed model is solved through two LP models. Furthermore the model is used to analyze the resource utilization of a bus manufacturing company. The results show that the own resources of the company is adequate for meeting the current demands. However, if the demand increases then the capacity will be insufficient. Under these circumstances, the model suggests to outsource some products that are currently produced by the company itself even for a price that is higher than their current costs.

In its current form, the proposed model is expected to provide an important guide to SC managers in their strategic plans, taking into account the fuzziness of the long term plans. The proposed model can be improved by offering more detailed methodologies for determining the fuzzy inputs. The application of the model has to be integrated with the enterprise resource planning software of the companies.

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# A STRUCTURAL EQUATION MODEL FOR MEASURING SERVICE QUALITY IN PASSENGER TRANSPORTATION

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**Abstract** — *With the improvement of the customer based management approaches, the firms have to consider the costumers' needs and wants in their activities and also they have to look the events and products with customers' perspective. In this paper, the variables are analyzed which have effects on customers' loyalty such as service quality, sacrifice, service value and customer satisfaction in passenger transportation with airways. Also the interrelationships are analyzed among these variables. The model which was proposed by Demirel et al. (2006) is used for predicting customers' loyalty in airway sector. In an application section there are 224 questionnaires from 6 different airway companies in Turkey for domestic flights. The data was analyzed with SPSS 12.0 and LISREL 8.80 packet programs. SPSS 12.0 was used for analyzing reliability and normality and LISREL 8.80 was used for analyzing model fit and structural equation model analysis such as path diagram.*

**Keywords** — *Airways, loyalty, satisfaction, service quality, service value, structural equation*

## INTRODUCTION

Loyal customers are very important for all firms in all sectors but especially for passenger transportation sectors. In airways, the firms' main structure are based on customers' needs and wants. In this sense, the firms have to support the high quality products and services in their activities. Service quality levels affect the firm's competitive advantage and they determine market share and profitability. The key variables normally considered when modeling passengers' decision-making processes include service quality with expectation and perception, sacrifice, service value, customer satisfaction and customers' loyalty.

In this paper, the variables are analyzed which have effects on customers' loyalty such as service quality, sacrifice, service value and customer satisfaction in passenger transportation with airways. Also the interrelationships are analyzed among these variables. The model which was proposed by Demirel et al. (2006) is used for predicting customers' loyalty in airway sector. In an application section there are 224 questionnaires from 6 different airway companies in Turkey for domestic flights. The data was analyzed with SPSS 12.0 and LISREL 8.80 packet programs. SPSS 12.0 was used for analyzing reliability and normality and LISREL 8.80 was used for analyzing model fit and structural equation model analysis such as path diagram. With the model which is used in this paper service quality can be measured in passenger transportation. Our study both synthesizes and builds on the efforts to conceptualize the effects of service quality, sacrifice, service value and customer satisfaction on customers' loyalty.

The rest of this study is structured as follows: The first part describes literature review about service quality in airway services. Next part discusses the Procedure, methodology, the research model, criteria and results of empirical study. The final results of the empirical study are presented and discussed in the final section.

## THEORETICAL BACKGROUND

Recent marketing research defined loyalty as a deeply held commitment to repurchase or repatronize a preferred product or service consistently in the future. Customer loyalty research has provided theoretical justification for viewing satisfaction as an important antecedent to loyalty, and has empirically showed significantly positive relationships. Prior research frequently suggests that loyal customers are likely to provide new referrals through positive word of mouth. They buy more products and resist competitive ressure. Guest loyalty was used as an intervening variable that has a time dimensional effect on repeat

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purchase and word of mouth. Benefits and trust are the most important antecedents to guests' loyalty and loyalty results in increased product use [2].

In the airline industry context the problem is whether management can perceive correctly what passengers want and expect. Moreover, expectations serve as standards or reference points for customers. In evaluating service quality, passengers compare what they perceive they get in a service encounter with their expectations of that encounter. Assessing passenger expectations is not a static exercise as passengers are becoming increasingly sensitive to quality. However, not all service dimensions are equally important to all passengers, because no two passengers are precisely alike, especially when demographics; purposes of travelling and ethnic background is considered [3].

The key variables normally considered when modelling passengers' decision-making processes include service expectation, service perception, service value, passenger satisfaction, and airline image. Understanding what consumers expect from a service organization is important because expectations provide a standard of comparison against which consumers judge an organization's performance. Airlines need to understand what passengers expect from their services. To date, the effect of air passengers' expectations on service perception and passenger satisfaction has not been fully investigated, even though it is an important commercial consideration [4].

In the passenger airline industry, only the customer can truly define service quality. The quality of airline service is difficult to describe and measure due to its heterogeneity, intangibility and inseparability. Nevertheless, quite a few conceptual and empirical studies have been devoted to investigate the service quality issues in the passenger airline industry. Various schemes for defining service quality dimensions or attributes have been proposed from the perspective of passengers. Most of these schemes are presented as quality measures for examining the relationships between service quality and related issues such as airline choice, customer satisfaction, customer loyalty, passenger type, airline type, airline class, aircraft type, productivity changes in quality levels over time, total transportation service offering, assessment group and attribute dependency [5].

For this paper our variables are service quality, service value, sacrifice, customer satisfaction and customer loyalty.

### **Service Quality**

Service quality can be defined as a consumer's overall impression of the relative efficiency of the organization and its services. Customer satisfaction can be defined as a judgement made on the basis of a specific service encounter. The importance of the relationships between airline service quality, passenger satisfaction, and behavioural intentions have been examined. Although the direction of airline service quality and passenger satisfaction has been studied empirically, the causal order between airline service quality and passenger satisfaction, and the exact relationship between airline service quality, passenger satisfaction and behavioural intentions, is still a matter of debate because the direction may vary depending on context [4].

### **Service Value**

Value can be defined as a customer's overall assessment of the utility of a product based on perceptions of what is received and what is given. Service value has been identified as an important variable of customer satisfaction and behavioural intentions. Even though studies have looked at service quality and value, the relationship between them still remains unclear. In spite of the importance of perceived service value as a form of assessment of services, there has also been only limited analysis of the exact nature of service value and its influence on customer behaviour. Previous airline service studies have often ignored service value and few have investigated the effect of service value on passenger behaviour [4].

### **Sacrifice**

Customer perceived sacrifice, which helps to integrate extant research and provides a more comprehensive picture about how customer value can be influenced. Sacrifice refers to what is given up or sacrificed to acquire a product or service. In fact, many customers count time rather than monetary cost as their most precious asset. Therefore, generally speaking, it is clear that there are two broad kinds of sacrifice: monetary costs and non-monetary costs. The former can be assessed by a direct measure of monetary cost of



the service or product and the latter can be defined as the time, effort, energy, distance and conflict invested by customers to obtain products or services [6].

### Customer Satisfaction

Customers have service expectations of an organization. Organizations are obliged to serve their customers. In the eyes of the service-profit chain theorists and champions of organizational quality, the closer the organization behaves in terms of what is expected of it by its customers, the more effective the organization. Similarly, and directly related to this research effort, the effectiveness of internal organizational service units can be measured by the degree of satisfaction of its performance by its internal customers (role set members). When members of internal organizational units satisfy the needs of their unit's internal customers, they also are enabling their internal customers to perform their tasks. By doing so, the network of organizational units are more apt to work effectively together to accomplish the overall customer service aims of the organization [7].

### Customer Loyalty

Early literature on loyalty involved a dual perspective with the views held by the researcher influencing the perspective taken. For example, researchers holding a deterministic view of loyalty advocated the need to consider loyalty from an attitudinal perspective while researchers holding a stochastic view considered loyalty from a behavioural perspective [8].

Traditionally, customer loyalty has been defined as a behavioral measure. These measures include proportion of purchase, probability of purchase, probability of product repurchase, purchase frequency, repeat purchase behavior, purchase sequence, and multiple aspects of purchase behavior. In the retailing context, following measures of customer behavior are commonly applied by practitioners – share of purchase (SOP) that measure the relative share of a customer's purchase as compared to the total number of purchases and share of visits (SOV) that measure the number of visits to the store as compared to the total number of visits. Other commonly used measures in the industry include Share of Wallet (SOW) – that is expenditure at a specific store as a fraction of total category expenditures which is analogous to share of purchase (SOP); Past Customer Value (PCV) – based on the past profit contribution of the customer; Recency, Frequency and Monetary Value (RFM) – measure of how recently, how frequently and the amount of spending exhibited by a customer [9].

## THE RESEARCH MODEL AND HYPOTHESIS DEVELOPMENT

Service quality can be regarded as a composite of various attributes. It not only consists of tangible attributes, but also intangible/subjective attributes such as safety, comfort, which are difficult to measure accurately.

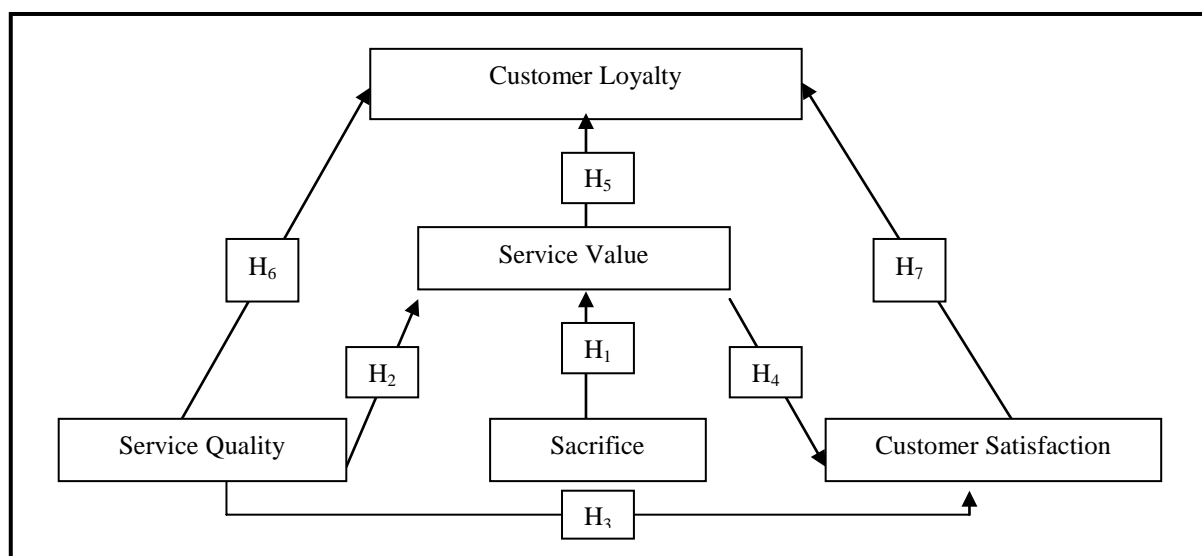


FIGURE 1  
The Hypotheses of Relationships between Model Variables

Different individual usually has wide range of perceptions toward quality service, depending on their preference structures and roles in process (service providers/receivers). In Figure 1 the research model and the relationships between model variables are represented with hypothesis. To measure service quality, conventional measurement tools are devised on cardinal or ordinal scales. Most of the criticism about scale based on measurement is that scores do not necessarily represent user preference. This is because respondents have to internally convert preference to scores and the conversion may introduce distortion of the preference being captured [10].

For this conceptual model we can develop seven different hypotheses.

- H<sub>1</sub> Sacrifice has a direct effect on service value.
- H<sub>2</sub> Service quality has a direct effect on service value.
- H<sub>3</sub> Service quality has a direct effect on customer satisfaction.
- H<sub>4</sub> Service value has a direct effect on customer satisfaction.
- H<sub>5</sub> Service value has a direct effect on customer loyalty.
- H<sub>6</sub> Service quality has a direct effect on customer loyalty.
- H<sub>7</sub> Customer satisfaction has a direct effect on customer loyalty.

TABLE 1  
Demographic Information of the Respondents (1)

	Alternatives	Amount	Percentage (%)
Gender	Female - Male	147 - 97	% 60.2 - % 39.8
Age	20 – 30 / 31 – 40	178 - 66	% 73.0 - % 27.0
Education	High School	10	% 4.1
	Before University	10	% 4.1
	University	157	% 64.3
	Master	67	% 27.5
Monthly income	Under 1000 YTL	5	% 2.0
	1000 – 3000 YTL	143	% 58.8
	3001 – 5000 YTL	76	% 31.1
	5001 – 7000 YTL	10	% 4.1
	7001 – 11000 YTL	10	% 4.0

TABLE 2  
Demographic Information of the Respondents (2)

	Alternatives	Amount	Percentage (%)
Which airway firm did you fly with in the last time?	Turkish Airlines	164	% 67.2
	Onur Air	20	% 8.2
	AtlasJet Air	35	% 14.4
	SKY Air	25	% 10.2
How many times have you flied with the same airway firm?	1	71	% 29.1
	2 – 5	123	% 50.4
	6 – 10	15	% 6.1
	11 - Above 11	35	% 14.4
What was the reason of your travel?	Work	96	% 39.4
	Personal	53	% 21.7
	Holiday	95	% 38.9
Who chose the airway firm?	Yourself	199	% 81.6
	Secretary	10	% 4.1
	Travel agent	20	% 8.2
	Family	5	% 2.0
	Other	10	% 4.1
What was the reason of your choice?	Service quality	25	% 10.2
	Low price	50	% 20.5
	Timing	79	% 32.4
	Casual choice	10	% 4.1
	Trust	60	% 24.6
	Other	20	% 8.2
How many times did you fly in last year?	1	40	% 16.4
	2 – 5	91	% 37.3
	6 – 10	68	% 27.9
	11 - Above 11	45	% 18.4

## METHODOLOGY

This research proposes an integrative model based on established relationships among service quality, sacrifice, service value, customer satisfaction and customer loyalty, and tests it in the context of airways firms in Turkey. The questionnaires were used for research. Subjects were asked to assess items of different constructs such as factors viewed as antecedents of customer loyalty such as service quality, sacrifice, customer value, and customer satisfaction in terms of their perceptions, based on a seven-point scale. A seven-point Likert-type response format ranging from “strongly disagree” to “strongly agree” was used for all items.

### Sample and Procedures

The sample was chosen from 6 different airways firms from Turkey. There were 217 passengers' questionnaires. Before the main research there was a pilot application to 60 respondents from different 3 airways firms. Respondents answered the questions with face to face pollster. The questionnaire contained six parts. Those parts were: perceived service quality, sacrifice, service value, customer satisfaction, and customer loyalty; there was an additional section for customer's demographic information. Table 1 and Table 2 represent demographic information of the respondents.

### Results of Structural Equation Modeling and Hypothesis Testing

Structural equation modeling was performed to investigate the relationships between the criterion variable of behavioral intention and the respective predictor variables of service quality, sacrifice, service value, and customer satisfaction. Figure 2 displays the structural model parameters and summarizes the degree to which the data fit the model.

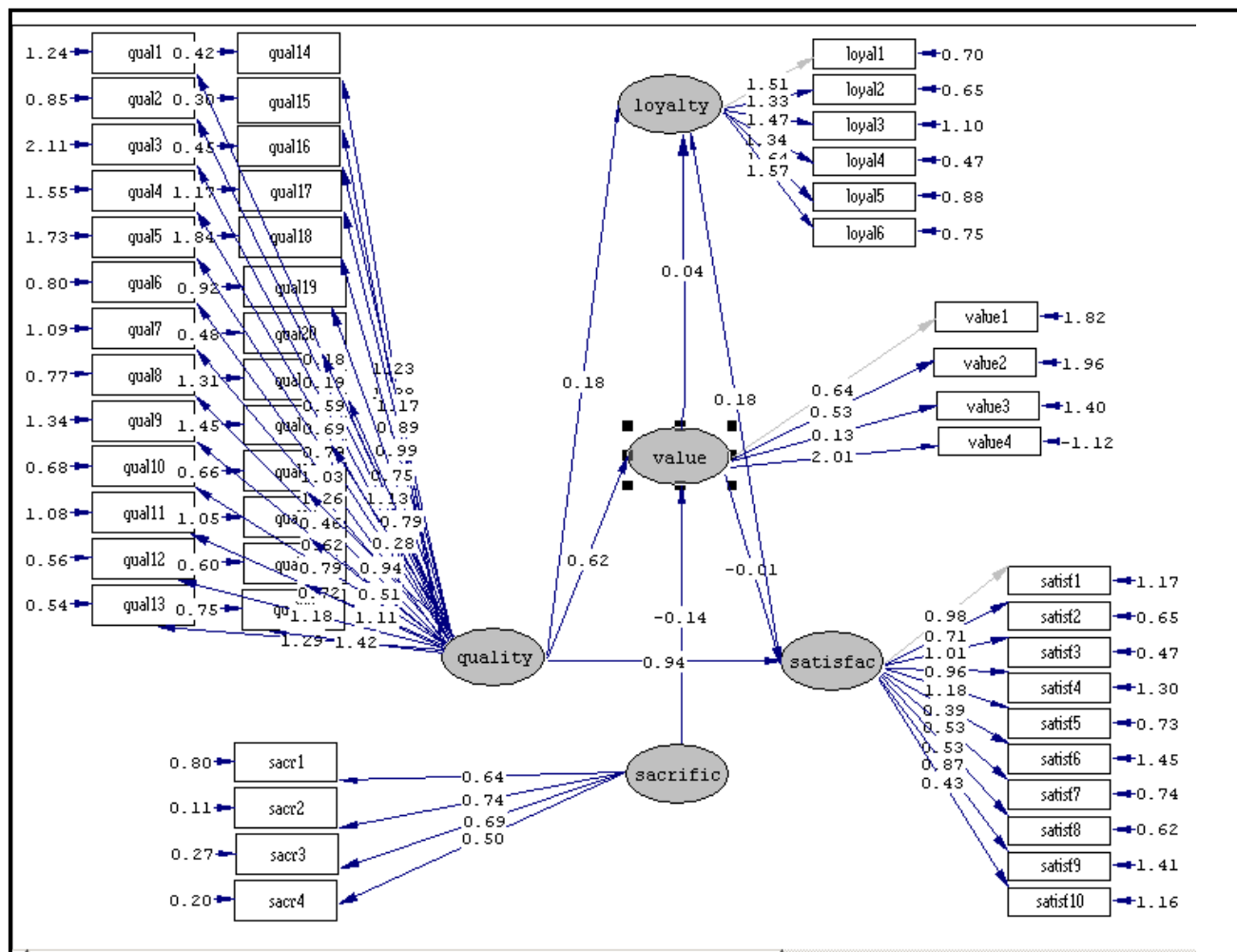


FIGURE 2  
The Path Analysis Results

TABLE 3  
Fit Indices for Measurement and Structural Models

Index	Value
$\chi^2/df$	13.244
Goodness-of-fit (GFI)	0.35
Adjusted goodness-of-fit (AGFI)	0.29
Root mean squared residual (RMR)	0.24
Root mean squared error of approximation (RMSEA)	0.19
Normed fit index (NFI)	0.63
Relative fit index (RFI)	0.61
Comparative fit index (CFI)	0.65

The GFI estimates the amount of variance explained by the model, and the AGFI adjusts this estimate by taking into account the degrees of freedom. Both of these estimates can vary from 0 to 1 [11]. The simplest fit index provided by LISREL is RMR. This is the square root of the mean of the squared discrepancies between the implied and observed covariance matrices. RMR has a lower bound of 0 and an upper bound of 1. Similarly to the RMR, the RMSEA is based on the analysis of residuals.

On the other hand, the NFI ranges from 0 to 1. An NFI of 0.95 means that the model is %95 better fitting than the null model. The RFI ranges between 0 and 1, with values approaching unity indicating a good fit to the data. CFI is based on the noncentral  $\chi^2$  distribution. The CFI also ranges between 0 and 1 [11].

The evaluation of this conceptual path model indicated a moderate goodness of fit ( $\chi^2/\text{degree of freedom} = 13.244$ , GFI= 0.35, AGFI= 0.29, RMR= 0.24, RMSEA= 0.19, NFI= 0.63, RFI= 0.61, CFI= 0.65). The goodness of fit index (GFI) value was lower than 0.8 and also the adjusted goodness of fit index (AGFI) value was 0.29. The AGFI value appeared lower. The RMSEA value was higher ( $>0.05$ ). This may indicate a level of discrepancy between the sample observed and the hypothesized correlations in the theoretical model. Although the normed fit index (NFI) value was lower than the commonly accepted value of above 0.90. Researchers have recommended comparative fit index (CFI) as a better fit index than NFI. Similarly, the CFI value for the current model was clearly a lower than the commonly accepted value of above 0.90 [11]. Since those indices all had values close to or below the level for superior fit, the proposed theory model was believed to have achieved a good model fit but not an excellent model fit.

The path coefficients are shown on the arrows in Figure 2. The results obtained from our analyses indicate that sacrifice has a direct negative effect on service value (-0.14) therefore the data does not support H1. This value is not significant. Because of its t value is equal -2.69. The t value must be above 1.96 [12]. Service quality has a direct and significant effect on service value (0.62) and thus H2 is confirmed. As confirmed in Figure 2, service quality has a direct effect on customer satisfaction (0.94), thus H3 is confirmed. Service quality has a significant effect on customer loyalty (0.18) and therefore H6 is supported. Service value has a direct negative effect on customer satisfaction (-0.011) therefore the data does not support H4. This value is not significant. Because of its t value is equal -0.37. Service value has a direct effect on customer loyalty (0.039) and thus we confirm H5. Figure 2 shows that customer satisfaction has a direct effect on customer loyalty (0.18), thus H7 is confirmed.

Thus, on one hand service quality has a direct significant effect on customer satisfaction; on the other hand it has direct and positive effects on service value and customer satisfaction. Similarly, on one hand service value has a direct and positive effect on customer loyalty.

## CONCLUSIONS

This paper has presented a model includes service quality, sacrifice, service value, customer satisfaction, and customer loyalty. By analyzing a set of 244 airways passengers, the study uses the structural equation model with LISREL 8.80 software to show that the sacrifice has a direct effect on service value, and has indirect effects on customer satisfaction and customer loyalty. Depending on this service value has direct effects on customer satisfaction and customer loyalty. Finally, the service quality has direct effects on service value, customer satisfaction and customer loyalty.

Overall, this research highlights the important role of three dimensions on customers' loyalty. Our findings indicate that service quality, service value and customer satisfaction lead to customers' loyalty. In

airway services managers should place special emphasis on the fact that of customers' perception of service quality, sacrifice, service value and customer satisfaction.

In airways services, in all airways firms service quality and service value is effective on customer loyalty. In airways transportation, the level of perceived service quality and service value are the major components of customer loyalty, besides in the assessment of the airways passengers may consider other factors such as price or reputation.

In future research, value scales of demographic features could be viewed as a variable in a new model.

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# ANALYSIS OF POTENTIAL GAIN FROM USING HYBRID VEHICLES IN PUBLIC TRANSPORTATION

İrem DÜZDAR<sup>1</sup> and Özay ÖZAYDIN<sup>2</sup>

**Abstract:** In the last two decades, the pollution in major cities was a growing concern. A significantly large contribution was made by road transportation sources to this problem. EU regulations on emissions and improvements in fuel quality sustained an improvement in air quality through reduction in pollutants. Latest trend taking the environmental issues into consideration in consumer car industry is hybrid vehicles, which use a conventional inner combustion engine using petroleum or diesel fuel, alongside with an electric engine, selectively using the necessary one depending on the current speed and power needs. As the vehicles equipped with this technology create less emission and consume less fuel, investigation of the potential gain when used public transportation is inevitable. In this study, a comparison-based study will be done between traditional busses using fossil fuel and new technology busses that the Istanbul Municipality selected as candidate fleet, utilizing energy, finance, environment and social responsibility aspects.

**Keywords:** Public transportation, Hybrid vehicles, Environment

## I. INTRODUCTION

Public transport, public transportation, public transit or mass transits are transport systems that transport members of the general public, usually charging set fares. The terms generally taken to include rail and bus services, and wider definitions might include scheduled airline services, ferries, and taxicab services. A restriction sometimes applied is that transit should occur in continuously shared vehicles, which would exclude taxis that are not shared-ride taxis.

Public transport may be regulated as a common carrier and usually provides scheduled service on fixed routes on a non-reservation basis, although share taxis provide an ad-hoc form of flexible public transport and demand responsive transport provides a pre-bookable form of public shared transport. Taxicabs and other vehicles for hire are generally fully flexible.

The majority of transit passengers are traveling within a local area or region between their homes and places of employment, shopping, or schools.

## II. EFFECTS OF PT ON ENVIRONMENT

The people moves from one place to another all their lives for various reasons. The distance moved is getting bigger as the cities growing. And they have to use vehicles to reach their destinations. In the developed countries well educated people use the public transportation vehicles. Public transportation has many of the advantages. It is more economical for the people, for the country and for the environment. It yields less noise, less pollution, less heat emission for the atmosphere, less money for fuel and vehicle, less area for roads and parking. [1]

## III. NEXT STEP: HYBRID VEHICLES

### Why would anyone buy a hybrid electric vehicle (HEV)?

First mass introduction to markets happened in 1999, and was a radical change in motor vehicle technology. Currently available HEV models achieve fuel economy increases of 10-40% [2]. compared to similar-sized vehicles, with commensurate reductions in greenhouse gas emissions. Some of HEVs' benefits are collective. Millions of people buying less-polluting and more fuel-economical cars can produce cleaner air and reduce risk of climate change, but no single HEV buyer can have much impact on these problems.

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Further, the private benefits of HEVs are unclear; reduced expenditures on fuel are routinely shown to be less than the vehicle purchase price premium of the hybrid vehicle over an assumed non-hybrid alternative. If private benefits are illusory and if collective benefits are not achievable by individual customers, why would anyone buy an HEV? Hopes that HEVs (or any new technology that promises collective benefits) can be successfully mass-marketed depend on answers to such a question [4].

### **An answer**

HEV not only provides its owner with transportation, but also provides symbolic meanings that owners can incorporate into better stories about themselves [3]. The symbolic meanings associated with HEVs are multiple and multi-layered, including widely recognized ideas like preserving the environment, opposing war, saving money, reducing support for oil producers, and owning the latest technology. But these denotations are linked to more personal connotations, such as concern for others, ethics, maturity, national independence, or individuality [4].

## **IV. HYBRID VEHICLES AS A PUBLIC TRANSPORTATION TOOL**

Hybrid-electric buses are being developed to answer specific challenges faced by today's public transport operators, range, fuel economy, emissions, and safety. Today's conventional buses still exhibit relatively poor fuel economy and moderately high emission levels while today's battery-electric buses cannot handle the demands of most transit duty cycles, specifically with respect to vehicle range. Hybrid buses are being developed in response to these challenges. Many hybrid-electric vehicles have evolved over time from initial work in the electric bus arena with assistance from both government and private programs [1]. Additionally, many urban areas where transit buses operate experience air quality problems that are also driving the decision to adopt alternative technologies. These include both alternative fueled traditional buses and hybrid buses.

A hybrid vehicle can be set up as a parallel configuration, where both the electric motor and the mechanical engine can drive the wheels, or as a series configuration, where only the electric motor drives the wheels. Different advantages and tradeoffs exist for each combination of components (Table 1 and Table 2)

**TABLE 1 - SERIES HYBRID [1]**

<b>Benefits</b>	<b>Trade-offs</b>
Fuel cell compatible	Greater energy losses as more energy passes through the energy storage device than in parallel hybrid
Reduced emissions – engine rarely idles and tends to operate in a narrow peak efficiency band	Maximum power at high speeds may only be available with both the APU and energy storage device operating
Improved low speed acceleration – all the power is routed through the electric motor providing high torque at low speeds	Lower steady state efficiency as generator is required to convert engine energy to electric energy and back again into mechanical energy
Numerous component layout options, simpler packaging	Increased weight – smaller APU will increase reliance on batteries and may require more batteries (weight) and may shorten battery life

Most of the countries now import more than half of the oil it consumes annually. The trade imbalance created by oil imports poses a major threat to the nation's economy should foreign sources of fuel become disrupted. Governments have directed federal agencies to develop programs to reduce the nation's consumption of imported fuels. One of the primary strategies has been to support the development of advanced vehicle technologies, like hybrid-electric, that reduce fossil fuel consumption overall and can utilize domestically produced fuels such as natural gas.



TABLE 2 - SERIES HYBRID [1]

Benefits	Trade-offs
More overall power – both engine and motor can supply power simultaneously	Generator rotor must spin when using energy from engine, adding more mass and rotating inertia
Reduced weight – smaller energy storage capacity possible compared to series hybrid	Less capable of capturing all available regenerative braking energy
Greater energy efficiency during steady state operation – not all energy must go through generator and electric motor as with series hybrid	Not fuel cell compatible
Greater battery life as batteries are used primarily for regenerative braking and acceleration assist, not for primary acceleration	

A diesel engine is currently the most efficient power supply available to the transit industry. In a conventional bus, current diesel engines are about as efficient (~30% overall) as they can get, although direct fuel injection will be used in the future to force some small efficiency gains and emission reductions. The reason this increase is expected to be small for conventional buses is that engine efficiency is dominated by the operating cycle and excessive idle time and not necessarily by the peak efficiency of the engine. In a hybrid-electric vehicle, however, the engine is not coupled mechanically to the wheels and can be operated more efficiently or, in some cases, turned off completely.

In slow urban drive cycles, nearly 50% of the energy expended by the vehicle is utilized for acceleration while the remaining energy goes to auxiliary systems and road load. If all the kinetic energy could be captured it would potentially double current transit bus fuel economy? Real world system limitations usually result in a maximum capture of about 50% of the available kinetic energy during regenerative braking. By recapturing 50% of the total kinetic energy (25% of the total expended energy), fuel economy is increased by 33%. [5]

The European Commission (2001) states in their White paper (European transport policy for 2010), that logistics can contribute to one of the objectives through: reducing the environmental impact of transport (e.g. improved vehicle utilization).

Two general approaches for reducing the environmental impact can be identified. The first is to rely on new, more energy efficient technology, which for public transport has proven to be insufficient. The second is to rely on companies to restructure their processes. In the public transport literature (the micro perspective) two methods to reduce the environmental impact are to either introduce more energy efficient technology, or to organize in a different way. However, it is not enough to introduce new technology to stop the development, e.g. more energy efficient engines. There is a need for larger structural changes in public transport.

A hybrid-electric bus is defined as carrying at least two sources of energy on board the vehicle, with an electric drive to provide partial or complete drive power to the vehicle's wheels. In most cases the two sources of energy will be an electrical energy storage device and an APU (auxiliary power unit). In a conventional bus, the diesel engine generates power that is mechanically transferred to the wheels through the transmission and differential. In a hybrid-electric drive bus, the engine produces electricity and may not be coupled to the wheels. Power is electrically transmitted to the wheels by a combination of the engine generator set and traction batteries. Although simple, the components of an electric drive system may only be well understood by transit agencies that operate electric trains or trolley buses.

### Owning Costs

Here we will try to provide an understanding of the cost factors involved with owning and operating hybrid electric drive buses. Since the technology is new it is impossible to use hard numbers on the cost to own and

operate these buses. Recent buyers have paid between 840.000 and 440.000 USD/bus. But in 1999 New York City Transit paid 385.000 USD/bus for 125 hybrid buses.

### Fuel

By definition HEV's consumes at least two different fuels, and these different fuels costs must be considered to estimate the operating costs. One is diesel or natural gas, and the other is lead acid batteries.

TABLE 3. HYBRID BUS FUEL COSTS [1]

		Conventional Drive	Hybrid
Diesel	Fuel Cost ((\$/Gal)*1000)	720,00	720,00
	Fuel Economy (mpg*100)	350,00	450,00
	Annual\$/bus	5.554	4.320
	(\$/mile)*1000	210,00	160,00
	\$/bus life (*)	83.314	64.800
Electrical	Cost (\$/ACkWh) * 1000	80,00	80,00
	Annual MWnr/bus	0,00	2,60
	Annual/bus		208
	\$/mile		0,01
	\$/bus life (*)		3.120
Traction Batteries	Replacement Cost(\$/pack)		50.000
	Annual/bus		3.333,00
	\$/mile		0,12
	\$/bus life (*)		50.000
Total Fuel	Annual/bus	5.554	7.861
	\$/mile	0,21	0,29
	\$/bus life (*)	83.314	117.920
(*)	Based on 15 years life and 27000 miles per year.		

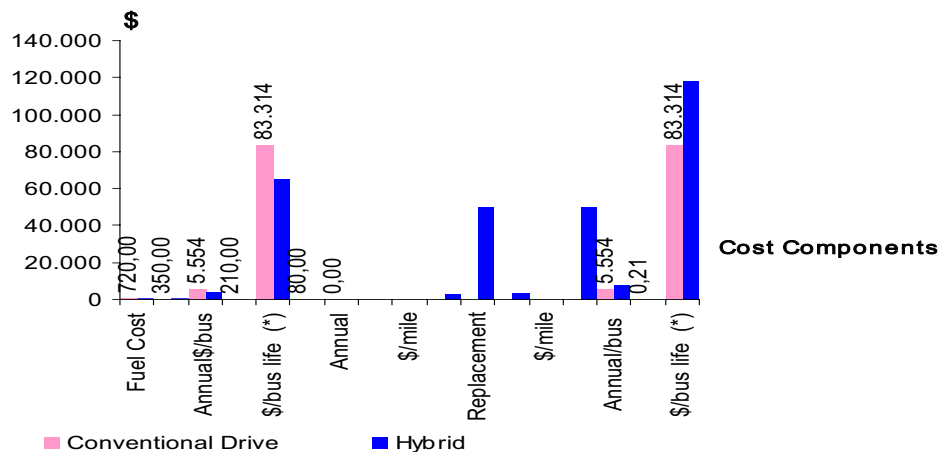


FIGURE 1. COMPARISON OF HYBRID BUS FUEL COSTS

The hybrid-electric drive definition problem is getting more unclear by the fact that the technology takes many forms and different labels to describe them. For instance, there are series and parallel hybrids, engine-dominant and battery-dominant hybrids, charge-sustaining and charge-depleting hybrids and dual-mode hybrids. All of these are currently under development and/or deployment and each has its advantages. Many perceived advantages are actually a function of the electric drive, which results in more available torque at low speed, smoother acceleration, and efficient regenerative braking. In either parallel or series

configurations the short-term benefit is increased efficiency due to the capture of kinetic energy through regenerative braking.

Hybrid-electric drive systems on transit buses are being aggressively investigated as a means of improving fuel economy, reducing emissions, and lowering maintenance and operating expenses. Several major federally funded research and development projects are testing the viability of these drive systems on buses. With the rapid pace of development and improvement of hybrid-electric drive technology, more transit agencies are being asked to evaluate the potential for hybrid-electric drive systems in their fleets. It is intended to provide transit managers with a better understanding of the technology, including benefits, challenges, and life-cycle costs.

In this paper, alternative fuels are considered for their potential to displace the oil is the main and only source of transport fuel. But we want to analyze only the hybrid electric buses among twelve different alternative fuel buses.

TABLE 4. AVERAGE VALUES OF WEIGHTS [1]

Criterion	Manufacture	Academic Institute	Research Organization	Bus Operator	Average
Energy Supply	0,0357	0,0314	0,0340	0,0249	0,0313
Energy Efficiency	0,1040	0,0943	0,1020	0,0748	0,0938
Air Pollution	0,1355	0,2090	0,1595	0,1605	0,1661
Noise Pollution	0,0452	0,0697	0,0532	0,0535	0,0554
Industrial Relationship	0,0923	0,0357	0,0480	0,0757	0,0629
Employment Cost	0,0900	0,0680	0,0343	0,1393	0,0829
Maintenance Cost	0,0300	0,0227	0,0114	0,0464	0,0276
Road Facility	0,1373	0,0953	0,1827	0,0803	0,1239
Vehicle Capability	0,0827	0,0590	0,1520	0,0283	0,0805
Speed of Traffic	0,1520	0,2420	0,1400	0,2637	0,1994
Sense of Comfort	0,0957	0,0730	0,0833	0,0523	0,0761

The evaluation of alternative-fuel buses should be considered from various aspects as; energy supply, energy efficiency, air pollution, noise pollution, industrial relationship, implementation costs, maintenance costs, capability of vehicle, road facility, speed of traffic flow, comfort. The AHP is used to determine the weights of evaluation criteria. The decision makers of the related industries as bus producers and operators assessed their subjective relative importance for each of the criteria. Table 4 shows the average values of weights. Then the next step is to evaluate the alternatives.

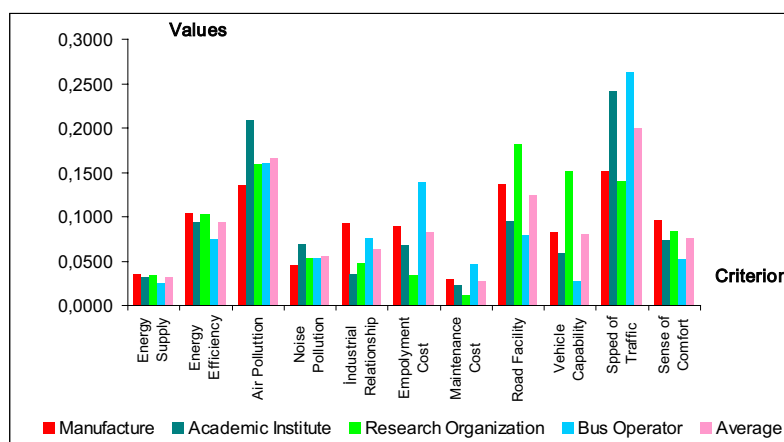


FIGURE 2. COMPARISON OF CRITERIA VALUES

TABLE 5. VALUES OF CRITERION FUNCTIONS [1]

Alternatives	Energy Supply	Energy Eff.	Air Poll.	Noise Poll.	Ind. Rel.	Empoly. Cost	Maint. Cost	Road Facility	Vehicle Capab.	Speed of Traffic	Sense of Comfort
Diesel Bus	0,82	0,59	0,18	0,42	0,58	0,36	0,49	0,79	0,81	0,82	0,56
Hybrid-Gas	0,77	0,63	0,63	0,52	0,66	0,63	0,65	0,67	0,70	0,80	0,74
Hybrid-Diesel	0,77	0,63	0,51	0,58	0,66	0,63	0,65	0,67	0,70	0,80	0,74
Hybrid-CNG	0,77	0,73	0,80	0,48	0,63	0,66	0,65	0,67	0,71	0,62	0,78
Hybrid-LPG	0,77	0,73	0,80	0,48	0,63	0,66	0,65	0,67	0,71	0,62	0,78

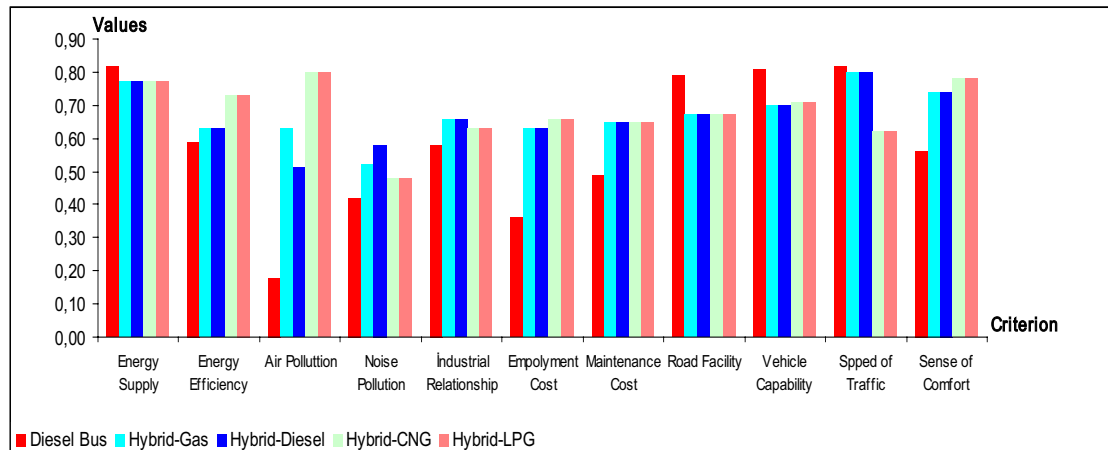


FIGURE 3. COMPARISON OF CRITERION FUNCTIONS

The major force behind the development of hybrid drive buses is emissions reduction. Hybrid buses are cleaner and emit fewer grams of pollutants per mile than conventional diesel buses. Hybrids have been shown to reduce particulates and NO<sub>x</sub> by as much as 50% during testing. Hybrid buses may be very desirable for highly industrialized countries [5].

TABLE 6. HYBRID BUS EMISSION CREDITS [1]

	Conventional Drive	Hybrid
PM g/mile	0,24	0,12
ton/year/bus	0,01	0,00
ton/year/100 buses	0,71	0,36
NO <sub>x</sub> g/mile	30,10	19,20
ton/year/bus	0,89	0,57
ton/year/100 buses	89,40	57,20
VOC g/mile	0,14	0,08
ton/year/bus	0,00	0,00
ton/year/100 buses	0,42	0,24
CO g/mile	3,00	0,10
ton/year/bus	0,09	0,00
ton/year/100 buses	8,91	0,30
CO <sub>2</sub> g/mile	2.779,00	2.262,00
ton/year/bus	82,54	37,18
ton/year/100 buses	8.253,63	6.718,14

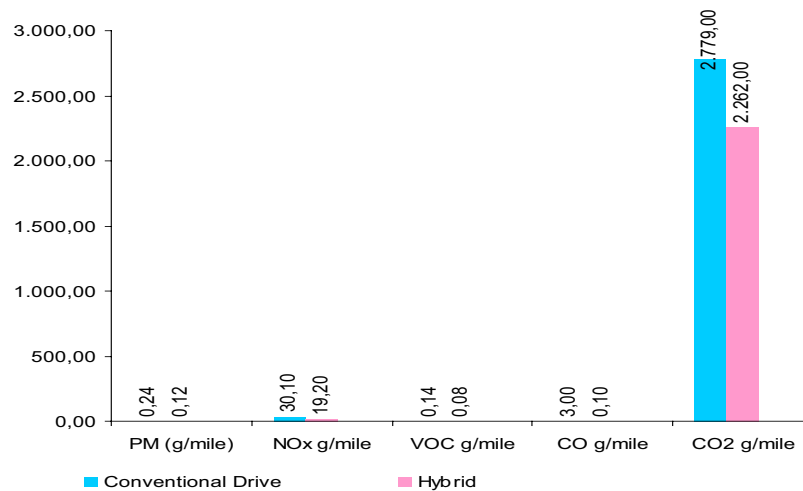


FIGURE 4. COMPARISON OF EMISSION CREDITS

Dual mode hybrids may allow limited zero emission range for operation in highly sensitive areas. For example, crowded downtown, tourist or historic areas might particularly benefit from pure electric (zero emission) propulsion mode of operation for short distances. In Boston, a new underground bus transit way is being constructed that will require buses to travel a 1.1 mile tunnel without burning fuel. Dual-mode hybrid buses might be particularly well suited to this type of application.

The major impetus behind alternative fuels is interest in reducing harmful emissions, improving public health, and conserving energy. Political, social, and environmental pressures are being placed on transit agencies to adopt alternative fuels and technologies including hybrid-electric drive.

Normal operating conditions for diesel buses range from 10°C to 85° C. Hybrid buses can perform in similarly demanding conditions; however, this will likely require some type of thermal management of the batteries. Lead acid batteries become less efficient when ambient temperatures drop below 45° C while other batteries such as nickel metal hydride may require active cooling at warmer temperatures. Regardless, hybrid drive system developers are designing thermal management into their battery management systems.

Hybrid transit bus maintenance costs are not well understood at this time. There is not yet enough operating experience with hybrids to realistically quantify the hours and costs associated with maintaining them. In practice, transit agencies experimenting with early hybrid prototypes report higher than normal maintenance costs which are typical for a new technology.

Hybrid technology can also have noise reduction benefits over conventional buses. Diesel bus noise standards typically specify that noise levels not exceed 83 dBA at any seat location in the bus at 50 km/h. Comparative noise data for hybrid bus was not available, but hybrid buses are quieter than standard diesel buses in service.

## V. RESULTS

Hybrid-electric drive technology introduces new opportunities and challenges in bus operation and maintenance. Hybrid drive offers operational advantages such as smoother and quicker acceleration, more efficient braking, improved fuel economy, and reduced emissions. Maintenance requirements may initially increase due to energy storage system requirements; however, these may go away once the technology develops. In the long term, hybrid bus maintenance may be less difficult than conventional mechanical technology due to savings associated with transmission and brakes. Infrastructure modifications are expected to be minor. Mechanical and safety retraining is needed in light of high voltage components. Transit providers must understand the issues and risks involved in deploying hybrid drive technology.

Successful introduction of a new technology into the bus fleet ultimately depends on both the commitment from management and a successful management plan. Hybrid drive will present public transportation managers with new challenges in the areas of operation, maintenance, labor, cost, and public relations. A management plan must address each of these issues and receive the full support of the agency's leadership. Addressing the nuts and bolts of infrastructure, hardware, and operating schedules will ensure success. Other human factors must be addressed as well, such as driver and mechanic acceptance. Employee acceptance can be won through careful training and rewards. Customer acceptance and public relations must also be carefully addressed. Hybrid technology may win supporters among public transportation users, elected officials and environmental constituencies for being quieter, smoother, and better for the environment.

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# OPTIMIZATION OF E-WASTE MANAGEMENT IN MARMARA REGION - TURKEY

*İlke BEREKETLİ<sup>1</sup>, Mijde EROL GENEVOIS<sup>2</sup>*

**Abstract** — *Electrical and electronic equipments have already begun to accumulate at the garbage dumps. This garbage accumulation brings big danger to the environment and to the human health. That's why we should look for exploring the ways to dispose of these wastes in an environmentally friendly manner. In this research, the recycling and disposal-landfill waste management strategies are chosen as the ways of treating WEEE. A model based on Badran and El-Haggar study with the conception of collection stations for WEEEs is proposed. The aim of this study is to select the places of collection stations by minimizing the e-waste management system cost for different scenarios. The criterion for choosing the optimal scenario is the minimum value of the objective function, which corresponds to minimum cost. Mixed integer programming is used to model the proposed system and its solution is performed by using LINDO.*

**Keywords** — *Mixed Integer Programming, Recycling, Separation Station Selection, Waste Management, WEEE (Waste Electrical and Electronic Equipment).*

## INTRODUCTION

Nowadays, technological developments increase day after day and we all see plenty of hi-tech samples in the global market. These frequently sold products created shorter life cycles for them. Hence, electrical and electronic equipments, which are a subset of technological equipments, have already begun to accumulate at the garbage dumps. The UNEP (United Nations Environment Programme) estimates that the world produces up to 50 million tons of Waste Electrical and Electronic Equipment-WEEE (or e-waste for short) per year. The current annual production of e-waste is 1.8 million tons in Germany, 1.5 million tons in France, and roughly 6 million tons in Europe. Unfortunately, quantity of e-waste in Turkey cannot be stated clearly because of the lack of statistical data. However, Turkey's annual e-waste production is assumed to be around 1 million tons, with reference to Germany's e-waste quantity. This assumption is made on the similarity between Turkey's and Germany's population and consumption habits. The European Commission identified the need for legislation to address the escalating problem of wastes, especially WEEE at the Community level, and this has taken the form of the WEEE Directive [1]. The EU's WEEE Directive (waste of electronic and electrical equipment) obligates manufacturers of electronic and electrical equipment to take back old equipment from customers free of charge and to dispose of these wastes in an environmentally sound manner [2]. Turkey, as one of the candidates for EU membership, is also on the way to prepare a new regulation about WEEE for the purpose of adaptation to EU's legislation. In the near future, this new regulation will be promulgated by Ministry of Environment and every EEE producer in Turkey should reform its organization and take the responsibility of its wastes.

The objective of this paper is to propose a model for e-waste management in Marmara region – Turkey, which incorporates the concept of separation stations, by taking base Badran and El-Haggar's (2006) study [3]. The proposed model will be optimized by minimizing the e-waste management system cost using mixed integer programming. The best location for separation stations is selected from the given candidate locations so that system cost is minimized. In the remaining part of the paper, waste management and its sub-topic e-waste management is mentioned. Section 2 includes some definitions and principles. The mathematical model to optimize e-waste management systems and to select the separation stations is represented in Section 3. Section 4 contains the scope of the application. Section five gives the results of the study. Finally in Section 6, conclusions driven from the research are provided.

## WASTE MANAGEMENT

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Waste management is the collection, transport, processing, recycling or disposal of waste materials. The term usually relates to materials produced by human activity, and is generally undertaken to reduce their effect on health and the environment. Waste management is also carried out to reduce the materials' effect on the environment and to recover resources from them. The purpose of waste management is to reduce the amount of waste being produced, thus reducing the disposal costs and the impact on the environment.

This means that reducing waste should be the primary concern. There are two principles in reducing waste, firstly to reduce the quantity generated and secondly to adopt an effective system to manage unavoidable waste [4]. Reuse and recycling are the best methods of dealing with waste that is unavoidable according to the hierarchy. Reduction and reuse are preferable to recycling, which requires waste to be re-processed before it can be reused [5]. The next best disposal route is incineration, which can also be used as a means of generating energy, although it does have some undesirable environmental effects. Finally, disposal in landfill sites is the least desirable option [6].

### WEEE and WEEE Management

Electrical and electronic equipment or 'EEE' means equipment which is dependent on electric currents or electromagnetic fields in order to work properly and equipment for the generation, transfer and measurement of such currents and fields falling under the categories set out in Annex IA and designed for use with a voltage rating not exceeding 1000 Volt for alternating current and 1500 Volt for direct current. [7] Waste electrical and electronic equipment is a generic term embracing various forms of electric and electronic equipment that have ceased to be of any value to their owners, or a waste type consisting of any broken or unwanted electrical or electronic appliance. There is, as yet, no standard definition [8]. EU's Directive 2002/96/EC defines 'waste electrical and electronic equipment' or 'WEEE' as follows: WEEE means electrical or electronic equipment including all components, subassemblies and consumables which are part of the product at the time of discarding [7]. In this paper, we will accept the definition of EU's Directive 2002/96/EC. Waste generated from electrical and electronic equipments is potentially hazardous due to heavy metal (zinc, cadmium, mercury, chromium and copper) effluent content. As such, they require special treatment and disposal techniques. At present, most waste arising from the industrial sector is released into the surrounding atmosphere, discharged into adjacent water bodies (rivers, streams, sea), stored on site, disposed of in privately owned landfills, incinerated in the open, or dumped haphazardly. [9]

There are generally three different ways of treating of WEEE: reuse, recycling and disposal (such as incineration, landfill) [10]. It is already said in section 2 that disposal in landfill is the least desirable option [6]. However, in Turkey's conditions, the reuse and recycling methods are much expensive and underdeveloped because the lack of technologies and know-how. So unfortunately, disposal in landfill is, for now, preferable to the other ways of treating e-wastes. In this search, the focus will be on recycling and disposal – landfill in order to reduce the disposed waste quantity and to dispose the rest in an environmentally friendly manner.

### MODELING

Separation stations are included in the proposed model for the e-waste management in Marmara Region. A schematic diagram of the waste flow of the system is shown in Figure 1. Six potential separation station sites in the chosen districts of Marmara are evaluated by the model to choose the best locations in order to minimize the system cost.

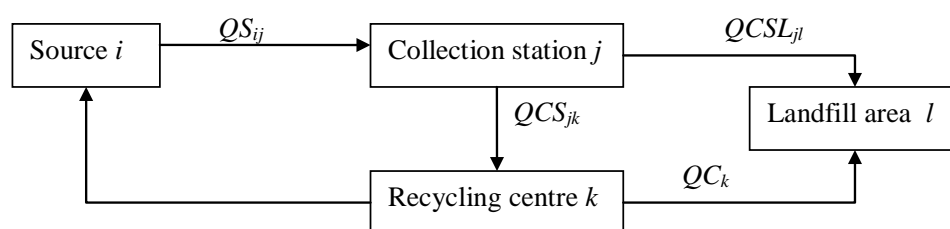


FIGURE 1  
Schematic diagram of the waste flow of the system



The objective is to select between the different potential sites for separation stations to minimize the total cost of the entire e-waste management system. The total cost is dependent on the facilities and is minimized by the mixed integer model.

### Assumptions

The assumptions made by Badran and El-Haggar are also accepted in this study, only with one exception. In their seventh assumption Badran and El-Haggar said that average vehicles speeds are determined as 25 km/h for the collection vehicles and 35 km/h for the transfer vehicles. In this paper, the speeds for both collection and transfer vehicles are assumed as 40 km/h.

In addition, in this study traffic jam, busy hours are not considered for the duration of the route in hours while transportation cost is calculated.

Distances between sources, separation stations, recycling centre and landfill areas are measured by Euclidean metric rule.

E-wastes are transferred to separation centres only from the sources in the same city. The only exception is the third separation centre. It is in Istanbul's Asian side however it accepts also e-wastes from Kocaeli.

### Formulation

The mathematical formulation of the mixed integer model will be as follows:

*Objective function:*

$$M = \sum_{j=1}^J i F_{n_j} D_j C_j \sum_{j=1}^J V_{S_j} \sum_{i=1}^I Q_i + \sum_{k=1}^K S_k \sum_{j=1}^J Q_j + \sum_{l=1}^L V_l \sum_{j=1}^J S_j \\ + \sum_{i=1}^I \sum_{j=1}^J T_{ij} Q_j + \sum_{j=1}^J \sum_{k=1}^K T_{jk} Q_k + \sum_{j=1}^J \sum_{l=1}^L T_{jl} S_j + \sum_{l=1}^L S_l$$

*Balance constraints:*

$$\sum_{j=1}^J Q_{ij} = G_i \quad \text{for } i = (1, \dots, I) \quad (1)$$

$$\sum_{j=1}^J Q_{jk} \leq (1 + R_k) \sum_{l=1}^L Q_{lk} \quad \text{for } k = (1, \dots, K) \quad (2)$$

$$\sum_{j=1}^J Q_{jk} \leq r_k \sum_{i=1}^I Q_{ij} \quad \text{for } k = (1, \dots, K) \quad (3)$$

$$\sum_{j=1}^J Q_{jl} \leq (1 - \alpha_l) \times \sum_{i=1}^I Q_{ij} \quad \text{for } l = (1, \dots, L) \quad (4)$$

*Capacity constraints:*

$$\sum_{i=1}^I Q_{ij} \leq C_j D_j \quad \text{for } j = (1, \dots, J) \quad (5)$$

$$\sum_{j=1}^J Q_{jk} \leq C_k \quad \text{for } k = (1, \dots, K) \quad (6)$$

$$\sum_{j=1}^J Q_{jl} \leq C_l \quad \text{for } l = (1, \dots, L) \quad (7)$$

$$Q_{ij} - M_j \leq 0 \quad \text{for } i = (1, \dots, I); j = (1, \dots, J) \quad (8)$$

$$\sum_{j=1}^J D_j \leq T \quad \text{for } j = (1, \dots, J) \quad (9)$$

*Non-negativity constraints:*

$$Q_{S_{ij}} \geq 0; \quad Q_{C_{jk}} \geq 0; \quad Q_{C_{jl}} \geq 0; \\ \text{for } i = (1, \dots, I); j = (1, \dots, J); k = (1, \dots, K); l = (1, \dots, L) \quad (10)$$

$$D_j = 0 \text{ or } 1 \text{ for } j = (1, \dots, J). \quad (11)$$

*Decision variables:*

There are four decision variables:

- $Q_{C_{jk}}$  : amount (in ton) of monthly e-waste to be transferred from separation station  $j$  to recycling centre  $k$  ( $j = 1, \dots, J; k = 1, \dots, K$ )
- $Q_{C_{jl}}$  : amount (in ton) of monthly e-waste to be removed from separation station  $j$  to landfill  $l$  ( $j = 1, \dots, J; l = 1, \dots, L$ )
- $Q_{S_{ij}}$  : amount (in ton) of monthly e-waste to be removed from district  $i$  to separation station  $j$  ( $i = 1, \dots, I; j = 1, \dots, J$ )
- $D_j$  : a variable of zero or one, which is to take one if a separation station is to be set up at candidate location  $j$  ( $j = 1, \dots, J$ ).

*Parameters:*

There are thirteen parameters involved in the system in order to calculate the decision variables:

- $CC_k$  : monthly capacity of the recycling centre
- $CCS_j$  : monthly capacity of the separation stations
- $CL_l$  : monthly capacity of the landfill
- $G_i$  : amount of monthly waste generated at source  $i$
- $FCS_j$  : fixed cost of the separation station represented as monthly fixed cost
- $VC_k$  : variable cost of the recycling centre represented per ton processed
- $VCS_j$  : variable cost of the separation station represented per ton processed
- $VC_l$  : variable cost of the landfill represented per ton processed
- $TCS_{jk}$  : transportation cost per ton of waste from the separation station  $j$  to the recycling centre  $k$  ( $j = 1, \dots, J; k = 1, \dots, K$ )
- $TCS_{jl}$  : transportation cost per ton of waste from the separation station  $j$  to the landfill  $l$  ( $j = 1, \dots, J; l = 1, \dots, L$ )
- $TS_{ij}$  : transportation cost per ton of waste from the source  $i$  to the separation station  $j$  ( $i = 1, \dots, I; j = 1, \dots, J$ )
- $T$  : number of separation stations
- $R_k$  : the percentage of the waste entering the recycling centre that is rejected.
- $r_1$  : ratio of WEEE transported from waste separation centre to the recycling centre. ( $r_1 = 0.1$ )

## APPLICATION

### Required data

The required data used in the application and their explanations are as follows:

$i$  : the index which indicates the waste sources. ( $i = 1, \dots, 15$ )

In Marmara region, Istanbul, Kocaeli and Bursa are the cities which generate the highest quantity of e-waste. For this study, we chose the districts of those cities as sources which produce the largest amount of e-waste and the organised industrial zones. In Istanbul seven districts, in Bursa five districts, and in Kocaeli three districts are determined. The waste generation sources are considered as point sources, located at the centroid of the respective district. The chosen districts can be seen on Fig.1.

$j$  : the index which indicates the separation centres. ( $j = 1, \dots, 6$ .)

In separation centres, collected e-wastes are controlled. If they are recyclable, they are sent to recycling centre. If not, e-wastes are transferred to the landfill.

By the assumption mentioned before in introduction, it can be said that Turkey's annual e-waste production is assumed to be around 1 million tons. In this study, the optimization is realized on monthly base. Therefore it can be assumed that approximately 83.000 tons of e-waste is generated every month. In addition, regarding the population of Marmara region, it can be assumed that the  $\frac{1}{4}$  of this e-waste quantity, ~20.000 tons, is emerged here. This information is needed for the second data, separation station data.

The separation station monthly capacity for e-waste is assumed to be 4000 tons. The location of these separation stations is determined according to adjacency to the most e-waste consuming districts. The location of the separation stations are shown in the map in Figure 2.

$k$  : the index which indicates the recycling centre. ( $k = 1$ )

This data is required for the recycling centre. In Marmara region, there is only one company which recycles the e-wastes. This company, EXITCOM ([www.exitcom.com](http://www.exitcom.com)), is located in Kocaeli. In this company, computers, printers, phones, mobile phones, cameras, electronic equipments, monitors, televisions, and home appliances are treated and recycled in the scope of e-waste management. Its e-waste recycling ratio is approximately 90%. Therefore  $R_k$  is given 10%.

$l$  : the index which indicates the landfill areas. ( $l = 1, 2$ )

In Marmara region, there are two different landfill areas to dispose of wastes. One is in Kocaeli and the other is in Gebze. The last data are required for the transportation costs. The transportation cost per ton for each route is divided in two parts. One is the transportation cost based on the distance traveled and the other is based on the duration of the trip.



FIGURE 2

The chosen districts (red marks) and possible separation stations (blue marks).

$$\text{Transportation cost per ton} = \text{Transportation cost per ton per hour} \times \text{duration of the route in hours} + \text{Transportation cost per ton per km} \times \text{distance in km.}$$

In order to calculate the transportation cost, the fuel cost is taken as 3,45 YTL/liter, the capacity of every long vehicle as 10 tons, vehicle cost as 100.000 YTL, and its useful life as 15 years. The duration of the trip will be calculated based upon average vehicle speed of 40 km/h for all routes.

## Results

The proposed model is solved using LINDO 6.01. The results of the modeling, total costs and selected separation stations are summarized in the Table 1.

**Table 1 The results of the modeling**

Total cost (YTL)	Selected Separation Stations
85.629.568	D1, D3, D5

## CONCLUSION

Nowadays, the depletion of resources and the pollution are two serious problems in the world. WEEE, or e-waste for short, is one of the most influential factors on these problems. E-waste is a generic term embracing various forms of electric and electronic equipment that have ceased to be of any value to their owners, or a waste type consisting of any broken or unwanted electrical or electronic appliance. While the hazardous substances in e-waste pollute the environment, their shorter life cycle causes the fast consumption and the continuous overproduction; hence the depletion of resources increases. To cope with these problems, governments should make law about waste treatment and the producers should take the responsibility of e-wastes. In this direction, e-waste management in Marmara region is modelled with the similar concept of having location stations as Bardan and El-Haggar's model. The model is solved using LINDO and optimal solution is obtained. Hence three of six separation stations are selected.

In this paper, the biggest problem is the lack of data about the detailed distance measures between the locations. The distance between different places is assumed to be the distance between their respective centroids and is measured by Euclidean distance. Additionally, traffic jam is not taken into account for the duration of the route in hours while transportation cost is calculated. Then again, the statistical data about the amount of e-waste generation is not known precisely and is assumed according some other data. The result of the presented model is based on some assumptions in the absence of the available data and could change with more accurate data. For the future work, another objective, such as minimizing the possessing time, can be added to the model and the goal programming approach can be used for the selection problem.

## ACKNOWLEDGEMENT

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# **Chapter 7**

Contemporary Topics in Transport and Logistics



# FUTURE PROSPECTS ON URBAN LOGISTIC RESEARCH

Rosário MACÁRIO<sup>1</sup>, Vasco REIS<sup>2</sup>

**Abstract** - urban logistics is a vital activity for the existence of urban regions. Yet, the very activity that maintains urban regions living is also endangering it. Solutions are therefore required to maintain and develop the current level of urban logistic activities without jeopardising economic and social development. Academia plays, in this sense, an important role on the design of those solutions. In this paper the authors discuss the main challenges currently affecting urban regions and discuss the principal solutions put into practice so far. Yet, urban logistic research is only now giving its first steps, and therefore suffers from the symptoms of a non-mature research area: lack of models and tools, absence of consensual definitions, lack of reliable data and data gathering methods. The authors in this paper identify seven research streams that if achieved would conduct the field of research on urban logistics to a next level of development and maturity.

**Keywords** — challenges, road map, urban logistics

## INTRODUCTION

Nowadays in Europe, urban areas concentrate, around 80% of the population, similar figures are found on other developed regions. In the developing regions, which traditionally had a larger rural population, people has been emigrating towards cities and urban regions in search for better employment and living conditions.

Social activity generates a great amount of demand for transport services, either related with human living, such as food, clothing, toys, furniture or waste transport; or related with business and industrial activity. The growth of urban regions has resulted in a continuous increase of freight transport activity [1][2]. Yet, the progressive increase of freight activity is no longer compatible with the current expectation and quality patterns of the population, particularly in developed countries and regions.

Urban logistics activities have been threatening urban regions' sustainability along the three dimensions of the concept: environmental, economic, and social. The main source of the problems is the physical flow of cargo within the urban region. Nowadays the large majority of those flows are done by road vehicles. A major problem is the worsening of congesting problems of the urban road network, particularly in the old town centres where road tends to be narrower. Road infrastructure is a scarce resource that private cars, public transportation vehicles and freight vehicles have to share. Congestion reduces quality of life and negatively affects economic development. The increase of freight transport activity naturally increases the number of conflict with other users. A second factor is the visual and sound intrusion of freight transport, and loading and unloading activities. Heavy trucks are noisier than private cars and therefore disturbing the quality of urban areas. This problem is worsened by the lack of suitable parking spots in many urban regions forcing truck drivers to parking vehicles anywhere possible (even going against the law), which is the source of many conflicts with both walking citizens and other traffic.

Urban freight transport activities are nowadays essentially based on road services, which have to share transport infrastructure with other users private cars. Furthermore, freight transport road vehicles tend to provoke more damage on infrastructure than private vehicles (both because are heavier and tend to have longer stops), increasing the public budget efforts in road maintenance. A growing number of complains and demands have been raised against the urban freight activities, searching for new solutions, less intrusive and damaging. Although, initiatives have been implemented and research efforts have been put into practice, yet so far with limited results. The truth is that knowledge on urban freight is still incipient and research in its childhood. So, some time will be required until positive measure could be implemented.

## DEFINITION OF URBAN LOGISTICS

An evidence of the initial stage of research and knowledge on a certain field is the lack of a consensual and universal definition on the object of analysis [3]. And, this situation is visible in urban logistics. Several

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definitions may be found on the literature. The Organisation for Economic Co-operation and Development, through the Work Group on Urban Logistics, proposed in 2003 the following definition for urban logistics [4]: *“The delivery of consumer goods (not only by retail, but also by other sectors such as manufacturing) in city and suburban areas, including the reverse flow of used goods in terms of clean waste”*. Several conclusions may be drawn from this definition. Firstly, urban logistics is restricted to urban areas. Therefore, freight flows that either cross; or start or end outside those regions are only within the scope of urban logistics while are geographically within the urban region’s boundaries. From here we may conclude that urban logistics may be part of longer logistic chains that either start or end within (or across) urban regions. Secondly, every freight flow produced within urban areas is considered as being urban logistics. Therefore, urban logistics is a very wide range concept, including a large diversity of situations with not necessarily any common point with the exception of being conveyed in an urban region. Thirdly, urban logistics also include the growing field of reverse logistics.

Yet, this definition has some limitations. Firstly, no mention is made to the agents in the context of urban logistics. And one of the challenges when researching on this area is precisely the large variety of agents involved. A definition on urban logistics should refer the agents. In this paper, all agents (both public and private) that have interests in urban logistic activities, are considered.

Secondly, the definition reduces logistics to the physical flows. Yet, similarly to what happens in logistics, other flows occur in parallel: information flow which corresponds to the exchange of information amongst agents, and contractual flow which corresponds to the liability and contractual terms established between agents. The very existence of these flows is recognised in the definition proposed by the Council of Logistics Management – CLM [5]: *“...is a part of the supply chain management process responsible for the planning, implementation and control of the efficient flow and storage of goods, and related services and information, from the origin to the destination point”*.

In this paper, as a result of previous research work<sup>3</sup>, the authors have adopted the following wide scope definition for urban logistics activity: *urban logistics is the process of distributing goods (including not only retail, but all economic sectors within cities and urban regions, including reserve flows of waste or not used goods. The process of distribution entails three types of flows: physical, logical and contractual. Finally, urban logistics agents are all those (private and public) agents that have any sort of interest, either commercial, social or other.*

## MAIN CHALLENGES

Urban logistic activity is inherently complex. Such nature raises several challenging difficulties which makes difficult the implementation of solutions.

Firstly, urban logistics is essentially a private sector, where agents are profit driven. They will seek to maximise profits and competitive positioning within market. Therefore, logistic companies have no incentive in engaging for more sustainable or less intrusive solutions, if that represents an increase of costs. By the very opposite they will strive to pass to others (mainly Society) all possible costs, generating externalities to the society as a whole. And, indeed, many of the urban logistic related problems occur because the responsible for causing it, are not paying the full costs of its action. Therefore, they have no incentives to change behaviour. This raises the need for regulation, so that externalities are properly incorporated in the activities that are provoking them. However, public intervention in urban logistics has had so far a rather narrow scope, being commonly limited to traffic restrictions (e.g. access times or vehicles’ dimensions) [2]. Moreover, there is a strong belief that an increase of costs in logistic activities would result in a decrease of economic competitiveness for the companies and, ultimately, of the whole regions.

Secondly, urban freight logistic problems are mainly dealt at local level, with local political authorities (such as municipalities). And, although the problems generated by urban freight activity being specific of the region, a national or supra-national would yield better results. This because certain solutions may require the intervention of higher levels on the political hierarchy, like for instance: changes in national legislation, or major urban interventions. Moreover, local authorities often lack the resources (equipment, budget) and knowledge to study and implement potential solutions. The absence of national or supra-national political intervention is patent in Europe, where there is a European Common Transport Policy that only deals with inter urban transport flows.

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<sup>3</sup> Done by the authors to the National Science Foundation in Portugal.



Thirdly, urban freight sector is made of complex labyrinth of agents with often divergent perspectives and goals. The main agents are: transport companies, shippers, clients, citizens, local authorities. Each group is by itself very complex, for example: transport companies range from global logistic companies (such as FedEx or UPS) to small delivery companies with few vehicles. In what the clients, these can be local shoppers that receive a delivery per week, until major retail shopping centres that receive several trucks per day. The key for the success on the implementation of solution relies at large extend on building consensus on the various groups of agents. Otherwise, if one or more groups do not agree or are suspicious on the intension of a certain measure, the most natural reaction is boycotting those initiatives [6].

Fourthly, urban logistic activity is very complex, and remains to some extend unknown, which is a consequence of the multiplicity of agents. Logistic operators have been developing tailored logistical solutions to better fit into the clients' demands [6]. Such evolution results in the existence of multiple flows of freight in an urban area, ranging from a single transport to a certain location within urban area, to complex routes with several stopover where some unloading or loading activity occurs, like for example: post delivery. Therefore, there are no universal solutions because each type of flow requires a particular way of approach.

Fifthly, the actual structure of an urban region is the result of a dynamic evolutions spanning in many case several centuries. Each step of development was done upon the existent infrastructure and with a certain purpose. An incremental process with different degrees of irreversibility at each step of the process. Naturally, in the past, neither the motorisation levels nor the sustainability awareness was as relevant as it is nowadays. Therefore, many cities lack suitable infrastructure for the realisation of urban logistic operations (namely, parking spots, terminals, sidewalks for small vehicles, etc.). Therefore, it will be necessary to redesign urban spaces or find creative solutions to overcome these physical limitations.

Sixthly, the validity and applicability of any research study depends upon the existence of reliable and useful information and data from the real world. Yet, there is scarcely available (and reliable) data on urban logistics activities, to large extend because this sector is done on a private basis. And, even when exists, data series tend to be recent, and normally do not coincide between regions (as this is normally a local initiative). This situation is in sharp contrast with inter-urban logistics (and freight transport) activity, where for almost every country (and even supra-national institutions such as the European Union, World Bank, OCED) there is a long tradition of collecting data. It will take some time until a coherent and adequate body of data would be built.

## WHAT HAS BEEN DONE SO FAR – GOOD PRACTICES

In order to tackle the challenges presented above, rationalisation of the distribution process (from the economic, spatial and temporal perspectives) is required. This means reducing the flow of goods yet keeping the adequate level of distribution to satisfy consumer's needs. As a way to achieve this, various solutions have been pointed out in several European cities. These solutions are not only aimed at the transport activity, but to the organization of the whole logistic chain. On some cases, the implemented solutions were adopted as "stand alone" solutions, focused on a specific case or problem; on some other examples, combined solutions were applied, i.e., several measures were implemented in a combined form, as part of a broad political strategy for urban logistics.

TABLE 1  
Measures implemented to solve the urban logistics problems

Type of Measure	Examples
Legislative and organizational measures	Cooperative logistic systems, encouraging night deliveries, public-private partnerships, intermediate delivery depots.
Access restriction measures	Access restrictions according to vehicle characteristics (weight or volume), conditioning access to pedestrian areas, urban tolls, periodic restrictions.
Territorial management measures	Creation of loading and unloading areas, of load transfers, and mini logistic platforms.
Technological measures	GPS, track and tracing systems, route planning software, intelligent transport systems, adoption of non polluting vehicles and vehicles adapted to urban characteristics (size and propulsion).
Infrastructural measures	Construction of urban distribution centres, and peripheral storing facilities, use of urban rail for freight (freight trams), underground freight solutions.

Generally, the different authors try to group the adopted solutions in accordance to different criteria [6][7][8]. In this work, we decided to group the measures identified according to their focus of application. This systematization can be found in Table 1, where they were placed according to the degree of intervention needed for their implementation (i.e., from "soft" to "hard" measures).

Some of the measures identified are very ambitious, while others lack the needed coherence and fail to achieve the goals for which they have been designed. This happens for a number of reasons, like the relative novelty [9] of the introduction of this subject on the urban management agenda, and also the lack of knowledge about the implementation processes involved in urban logistics and hence on the appropriate way to tackle the collateral problems accruing from these processes.

Nevertheless, it is already possible to draw some notes on the nature of initiatives already taken.

### **Cooperative logistic systems**

These correspond to cooperative schemes arranged amongst logistic agents, with the purpose of optimising (both in spatial and temporal terms) their freight distribution networks. The cooperation may be achieved at several levels, like for example: sharing of infrastructure or vehicles, or sharing of information [5].

Cooperative systems may result in a reduction of the costs of operations, due to both an increase of efficiency on the utilisation of resources and on the existence of economies of scale. On the other hand, this may increase the market of each individual agent, as they can use the others' resource to expand their services. Yet, these arrangements reduce the individual visibility of each agent, because the operations and customer relations are carried out by one of the agents. Moreover, there is an increase of communication costs, and complexity on the management of logistic operations. The need of aligning and coordinating the operations of several individual agents can be a difficult task.

### **Night delivery**

Night delivery has the main advantage of making use of road infrastructure in periods of lower or no congestion. Yet, freight operations tend to be noisy which can disturb sleeping residents. This drawback may be overcome with the adoption of proper technological solutions. Other problem is the increase of costs to the clients, because they will have to have workers to process the cargo.

### **Public private partnerships**

Public private partnerships initiatives are particularly attractive in those situations that require large investments and simultaneously have high risks. Public authorities and private investors agree on the share of risks and level of investment of each party. Often this is the solution to attract private agents into projects that otherwise would have to be managed by public authorities. The participation of private agents is positive not only because normally higher levels of efficiency if obtained, but also to promote economic development.

### **Urban logistical centres and urban terminals**

The implementation of medium to small size terminals within urban regions if used by more than one agent can generate important benefits [10]. Flows can be concentrated in larger trucks (thus reducing the number of vehicles in transit) to terminal and local distribution can be done using lighter vehicles (non-motorised). Moreover, these facilities increase the flexibility of logistical systems in the sense these facilities can be used as drop off and collection points for clients.

Yet, the creation of these facilities often require the involvement of public authorities owing to the larger initial and maintenance investments, which can be overcome through public private partnerships.

### **Legal Measures**

Simple changes on the legal framework for the access to road infrastructure may yield important benefits, namely, reduction of conflicts with other users; reduction of noise, emissions and congesting; or optimisation of public space. The drawbacks are an increase on the operations costs on both logistical agents that may have to change the logistical schemes or acquire new equipment and clients because they may have to extend their working period to receive cargo. Moreover, the success of these measures depends on an adequate enforcement.

These measures normally include the imposition of restrictions on the access. These restrictions can be either temporal (when logistic activities are banned during some periods of the day), spatial (when logistic activities are prohibited in some urban zones) or technological (when only certain vehicles can access a specific zone).

### **Technological Measures**

Technological measures can provide important solutions on the reduction of the environmental footprint of urban logistics activities. Technological measures include intelligent transport systems (ITS), information technologies (IT) and new transport vehicles (NTV).

ITS and IT enable higher integration and seamless flows amongst agents. Logistical systems may be optimised being possible to reduce operational costs. Higher ratio of vehicles' utilisation can be achieved, with a reduction on the number of necessary vehicles.

NTV concern the utilisation of new types of vehicles. These vehicles can have a different design, especially made for urban utilisation, or use new propulsion solutions, such as hybrid or electrical. NTV can help reduce pollution and noise problems on urban regions, yet, they still contribute for congestion and other problems.

### **WHAT IS MISSING - ROAD MAP FOR FUTURE RESEARCH**

Urban logistic sector is at a crossroad, on the one side, demand is raising with more and more need for logistical services, on the other side, populations and governments have been demanding a reduction of the burden generated by those very logistical activities. Although, we may envisage a tense relationship amongst these two parties, a dynamic equilibrium has to be found, in order to avoid jeopardising both urban living standards and economic development.

Academia at large and research in particular may provide an important help by depicting new solutions. Research on urban logistics is still in its childhood and a long way lies ahead until this field of research could reach the current level of development of other areas such as logistics. The authors have identified various needs of research, in order to help close the gap of knowledge and, in this way, promote the development of better solutions.

Modelling and simulation tools are nowadays a fundamental tool on the development and testing of potential solution in several fields of knowledge. However, very few steps have been achieved so far on the development of robust models. As already written one of the problems lies on the youth of urban research logistics, while the other lies on the lack of suitable data. Yet, owing to the large variety of actors and functions on urban logistics activities, the task of gathering data is daunting. Therefore, one main stream of research is the development of techniques for collection of data on urban logistics activities. Data should be comparable across regions and activities, so that multiple analyses could be carried out.

Other stream of research is naturally the development of models for the analysis of urban freight flows, and the evaluation of possible solutions. Once again, the multiplicity of urban logistic activities made the development of a universal model virtually impossible. Therefore, specific business case models should be developed, and only afterwards integration can be sought. Horizontal models that could analyse all types of traffics would be very important, so that conflict analyses could be carried out. In this sense, the relevance of the applicability of the traditional four steps models, whose philosophy is still nowadays widely used in the transportation field (people and logistics flows), should be adequately validated in the field of urban logistics. Several doubts have been put on the applicability of this model to urban logistics, namely, the fact that flows are generated in terms of origin and destination, while a large part of urban logistics have one origin and several destinations, along a path.

This problem leads us to a next area of research which is related with the generation of flows of goods. There is a major lack of robust models to generate flows of goods within urban regions. This absence limits the validity of any evaluation of a certain solution.

Another line of research concerns the integration of urban logistics activities with inter urban logistic activities. This urban part of long logistic chains is normally called as *last mile*, at present a major problem for both private companies and public authorities. The level of congestion and lack of suitable infrastructure makes delivery times unreliable and difficult to manage. Thus companies have to implement redundant systems or increase the number of vehicles to ensure the maintenance of quality levels, which ultimately results in an increase of the costs. A higher number of vehicles or illegal parking increases the burden over

urban environment. Therefore, a seamless integration and management of the last mile along with the rest of the transport chain is a win-win situation.

Urban logistic activities are, as already written, essentially private. Therefore, the success of any initiative depends on the maintenance of the competitive level and profit of the private agents. Nowadays, there is little knowledge on how to design urban logistics solutions that do not affect the competitiveness of private agents [6]. A deeper understanding on the actual strategies, competitive forces and business models of private agents would be of utmost importance for the development of business models for the implementation of urban logistic activities that would be neutral for the competitive balance between the agents.

A final stream of research concerns the regulation of urban logistic sector. Regulation and legislation may be used to promote the adoption of better urban logistic schemes, for instance, laws may define maximum levels of emissions, type of contracts, or nature of service. Yet, no specialised knowledge has been created on this area.

In summary, urban logistics is a vital activity for the existence of urban regions. Yet, the very activity that maintains urban regions living is also endangering it. Solutions are therefore required to maintain and develop the current level of urban logistic activities without jeopardising economic and social development.

Academia plays, in this sense, an important role on the design of those solutions. In this paper the authors discuss the main challenges currently affecting urban regions and discuss the principal solutions put into practice so far. Yet, urban logistic research is only now giving its first steps, and therefore suffers from the symptoms of a non-mature research area: lack of models and tools, absence of consensual definitions, lack of reliable data and data gathering methods, and lack of a sound research tradition.

The authors in this paper have identified seven research streams that if achieved would conduct the field of research on urban logistics to a next level of development and maturity.

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## AN ANALYZE OF RELATIONSHIP BETWEEN CONTAINER SHIPS AND PORTS DEVELOPMENT

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**Abstract** — *This paper focuses on the most important trends affecting the deep-sea container shipping industry with reflecting on significant increase in size of the ships employed as well as container port and terminal development. Such changes in the size and capacity of the largest containership were happened due to the strong growth in world container flows and ports throughput, the economies of scale in container ship operations, increasing competitive pressures in the liner shipping and port industry. The evolution in supply chains and logistics models urges liner shipping and container terminals to reconsider their function in the logistics process described with the trends in mega ships and mega container cranes in ports. The strategic analysis regarding the latest development of ULCC's, deployment patterns, and its implications in terms of shipping structure, impact on port authorities, infrastructure requirements and container terminal operational efficiency is given in this paper.*

**Keywords** — *Containerports and ships, Changes in ship and port environment, Relationship between ship and port*

### 1. INTRODUCTION

Container ships have reached a fifth or sixth generation development. Although some ports and terminals may face the problem of installing advanced systems for handling large numbers of containers per ship call, most ports will be providing for more modest service demands where present ship-to-shore container cranes and ground storage of containers will suffice.

While these large containerships will give a low cost per ton mile if they are running at capacity, their efficiency is impaired if their mode of operation is to call at several ports at each end of the journey to accumulate cargo. Container terminals can generate substantial amounts of land traffic mode, particularly when compared with logistics activity at regular container service.

The liner shipping and port industry has been reshaped by logistic integration, containerization, deregulation and globalization. Liner shipping companies and container terminal operators have become the most important part in the international supply chains, which are complex and logistics models. The evolution in supply chains and logistics models urges liner shipping and container terminals to reconsider their function in the logistics process described with the trends in mega ships and mega container cranes in ports. These performances require the new ideas and concepts in container terminal planning in order to keep pace with the development of the mega container vessels. All before mentioned is summarized on Figure 1 [6] and [7]. This figure describes the close connection between trends in container shipping and development of container maritime and intermodal logistics. Figure 2 gives maximal container ship sizes by year of built [6] and [7].

This paper is organized as follows. In Section 2 we give a brief description of the container ship development. In Section 3 we review the related world container port and discuss main topics regarding the world maritime container trade. Section 4 evaluates and compares various cases of relationship between port and ship systems. This implies a visual impact of what has happened to ship-to-shore cranes (QC – quay crane), container ships and terminals in 45 years. Thus, we present effect on container terminals with numerical results and computational experiments which are reported to evaluate the efficiency of the Pusan East Container Terminal (PECT) layout. Finally, we conclude with the consideration about future container port trends in the coming years.

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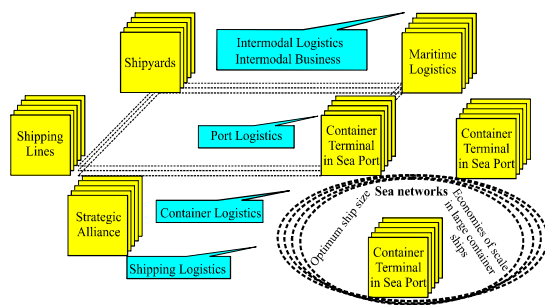


FIGURE 1

Background of container ships operation

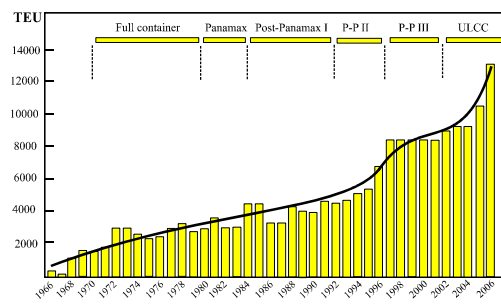


FIGURE 2

Maximum container ship size by year of built

## 2. CONTAINER SHIPS DEVELOPMENT

The capacity of world container fleet is more than 10 million TEU in operations and about 3.0 million TEU on order in the 2007 and 2008. World cellular fleet capacity is around 9.6 million TEU. According to the carrying capacity cellular ships take part with more than 75% in the structure of the world container fleet. This represents the increase of more than 15% than in 1995. So, in the period of 1995 to 2007, the carrying capacity of cellular ships increased for more than 3.5 or from 2667602 TEU to 9610813 TEU. Also, average TEU per ship in 1995 was 1548 and, in 2007, an approach to 2399 TEU per ship or it is increasing of 64%. While, at the end of 1995 there were 392 cellular ships with the carrying capacity more than 2500 TEU which presents the total capacity of 1296635 TEU, at the beginning of 2007, there were 1128 ships with the carrying capacity above 3000 TEU with total of 5764656 TEU or almost 60% of total cellular fleet capacity.

The largest mega container ships in service today with capacities between 8680 and 14500 TEU, now represent 2.5% of the world fleet of container ships, 9% by total seagoing capacity of cellular ships. Also, the largest of the ships currently on order have capacities of more than 12000 TEU, and there is clearly scope for even larger ships. Figure 3 shows container ship development in relation to generation of ships [5]-[7], [10] and [11]. The composition of cellular fleet is presented in Figures 4 and 5 [5] and [6]. Figures 6 and 7 demonstrate projection of containership fleet growth from 2006-2008 [5], [6], [11] and [12].

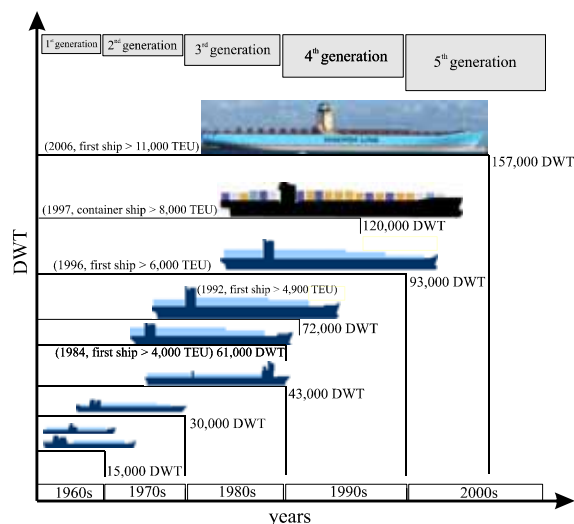


FIGURE 3

Container ships development

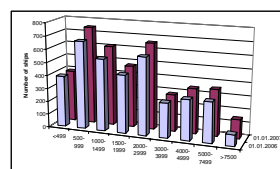


FIGURE 4

Deliveries of CSs by number of ships per ship classes

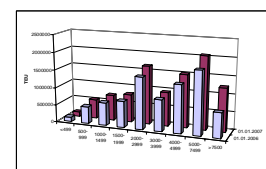


FIGURE 5

Deliveries of CSs by carrying capacities per ship classes

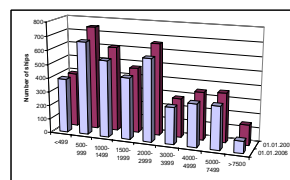


FIGURE 6

Number of ships per ship classes 2006 &amp; 2007

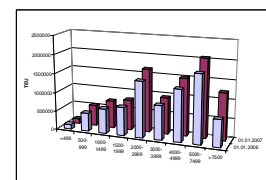


FIGURE 7

Carrying capacity per ship classes 2006 &amp; 2007

## 3. WORLD CONTAINER PORTS DEVELOPMENT

World container throughput had almost 6 times in the last twelve years and reached 417 million TEUs in 2006. The world top six busiest ports in 2006 are the East Asian ports surrounding China, which accounts for 26% of the world container throughput (see Figure 8).

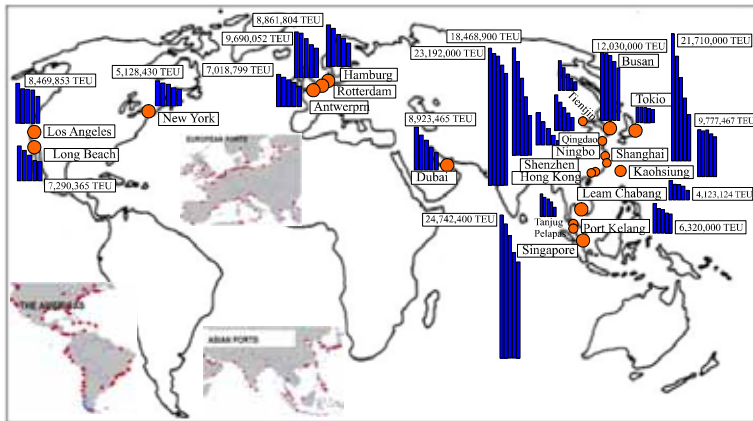


FIGURE 8

Major World Container Ports in 2006 with container traffic development: 2002-2006 [1], [2], [6], [7], [9], [10], [13] and [14]

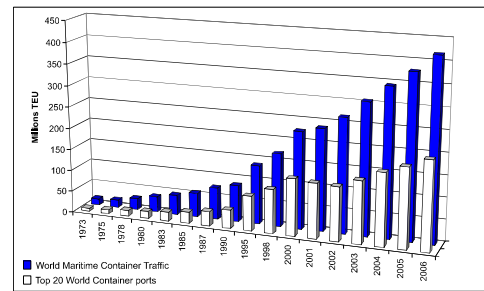


FIGURE 9

World Maritime Container traffic and 20 Top World Ports: 1973-2006 [2], [6] and [7]

Over time, the use of oceanborne containers to transport international trade has affected the distribution of total maritime trade among world container ports. The increasing number of container shipments causes higher demands on the seaport container terminals, container logistics and management, as well as on technical equipment. So, Fig. 9 shows trend functions of world maritime container traffic in last 33 years. Also, container traffic of the 20 largest seaports in the world from 1973 to 2006 is shown on Fig. 9.

Five decades ago, the containership revolution started in the world, changing how the world handles international freight transportation. In 2006, world maritime container traffic was estimated at 417 million TEU, 10 percent more than the 378 million TEU transported in 2005. The world container port ranking changed significantly between 1995 and 2006. The total container traffic volume of the 20 top ranking world container ports reached 205.3 million TEU in 2006. These ports increased their handling volume by 10.4 per cent compared with results in 2005, representing approximately 50 per cent of the total world container traffic. New container ports gained momentum (like Tanjung Pelapas) and other ports established their role as international load centres. Today the largest world container ports are located in Asia.

Like in previous years especially Chinese ports saw a constant growth at a very high level. Even though the container traffic of the Chinese container ports grew on average by 25 per cent, the growth did not reach last years values. All in all, the strong growth of Chinese container ports is dominating port traffic not only on a regional but on a worldwide level.

#### 4. AN ANALYSE OF RELATIONSHIP BETWEEN CONTAINERSHIP AND TRANSSHIPMENT HUB PORT

Generally speaking, the competitive environment for container ports has changed drastically in recent years. Particularly, in the area of container shipping, a port will gain a significant share of the business only when it can demonstrate a combination of rates, facilities, and inland connection that create a clear competitive advantage for an identified group of customers.

Figure 10 gives a visual impact of what has happened to ship-to-shore cranes (QC – quay crane), container ships and terminals in 45 years [6] and [7]. Structural engineers have had the task of keeping up with size, weight reduction, fatigue life, etc. The civil engineers keep driving more piles to support what the structural engineers develop. This figure is a base reference here for illustration and comparison. It shows three basic subsystems: QCs, container ships and terminals.

A way has been found to calibrate the combined effect of container shipping (ship development), port container terminal (terminal development) and ship service time with handling costs (average cost per ship service) on the main container port link (berth-ship including different layout of container yard for container storage) for main four generation of ship, terminal and container quay crane evolution, by making certain assumptions which are described in Figure 10. The relationship between ship size with average cost per ship served and terminal system costs is available from Figures 10-i and 10-l, while Figure 10-j shows that the shorter the route length, the flatter is the line graph showing total shipping cost per TEU (as one would expect, this implies that the economies of ship size are of greater benefit on longer routes (see, [3] and [4]).



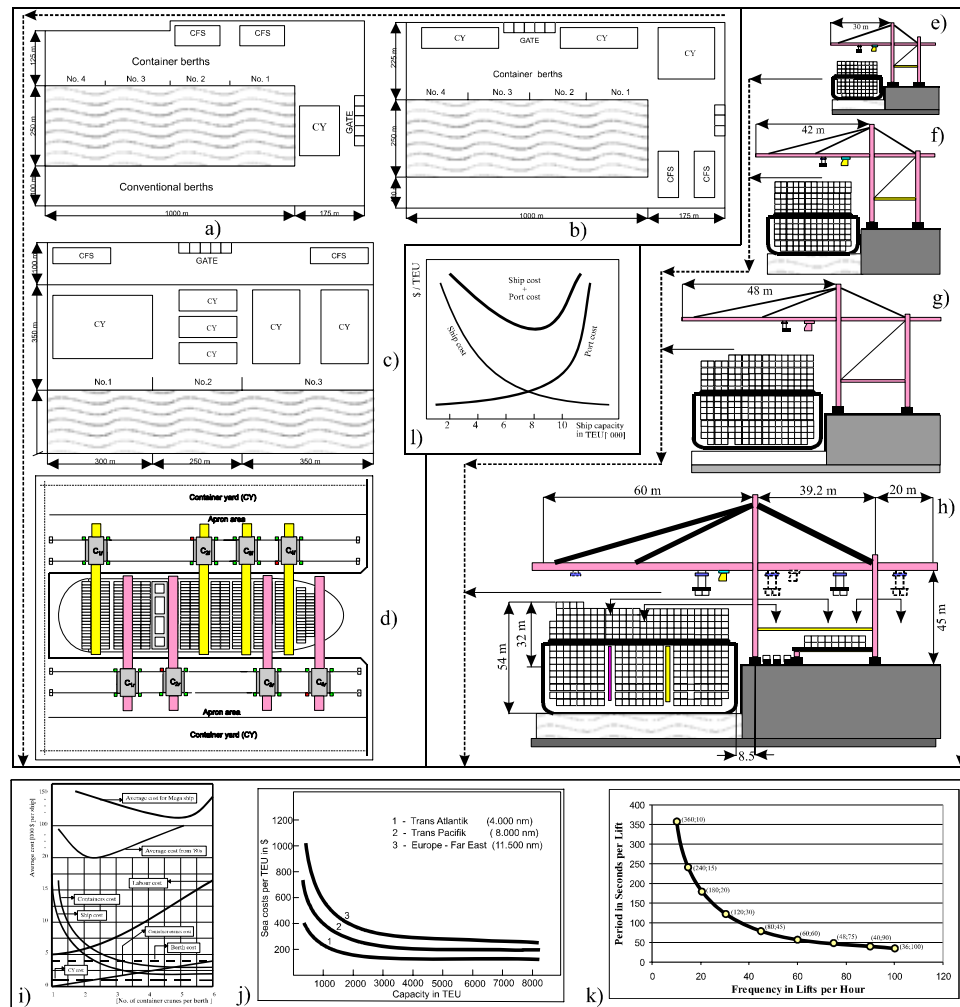


FIGURE 10

The relationship between ship size, container quay crane and terminal layout development

Graphs 10-i,j,k and l provide quantified sets of curves for average ship cost in port, total port or terminal system cost, container ship cost per TEU related to size of ship in relation to a number of different lengths of voyages and ship service time in hours vs. lifts per hour. They are based from previous investigations [3], [4] and [5]. Figure 10-a shows the layout of the New Basin Container Terminal, comprising four berths offering berthing space to four second-generation container ships or, alternatively, to three third-generation container ships. It can be seen from drawing that the port opted for a pier-type configuration.

Figure 10-a shows the layout of the New Basin Container Terminal, comprising four berths offering berthing space to four second-generation container ships or, alternatively, to three third-generation container ships. It can be seen from drawing that the port opted for a pier-type configuration. This type of terminal focuses attention to some areas of terminal performance for improvement of general layout from perspective continuous evolution of ship size. Consequently, Figures 10-b – 10-d give a visual impact of what has happened to terminal layout in 30 years. The new concept port layout regarding efficiency handling system can be explained in two variants (see Figures 10-c and 10-d). Container quay cranes can be either renovated or developed as new concept that are different from existing methods in order to facilitate improved productivity in berth (Figures 10-e – 10-h).

#### 4.1. Effect on container terminals development

The results of this study imply that the economies of container ship operations are now, and are likely to be, such that terminal operators must provide excellent service guaranteeing safety, on-time service, and accuracy. To do that a hub ports facilitate adequate port facility, equipment, and handling system. In addition, average cost per ship service and any costs involved in transshipment must be minimized.



This subsection gives a ship-berth link modeling methodology based on statistical analysis of container ship traffic data obtained from the PECT. Implementation of the presented procedure leads to the creation of a simulation algorithm and analytical methodology that captures the ship-berth link performance well. The efficiency of operations and processes on the ship-berth link has been analyzed through the basic operating parameters such as average service time, average QC productivity and average number of QCs per ship. PECT is big container terminals with a capacity of 2008573 twenty foot equivalent units (TEU) in 2005. There are five berths with total quay length of 1500m and draft around 14-15 m, Figs. 11 and 12 [8]. Ships of each class can be serviced at each berth.

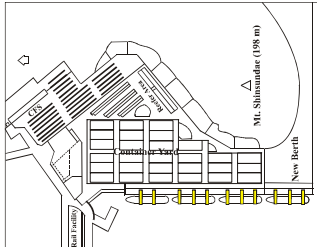


FIGURE 11  
PECT layout, 2005

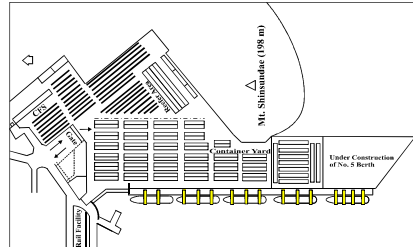


FIGURE 12  
PECT layout, 2006

The input data for the both simulation and analytical models are based on the actual ship arrivals at the PECT for the ten months period from 1 January 2005 to 31 October 2005 (Fig. 11) and 1 January 2006 to 31 October 2006 (Fig. 12), respectively [8]. This involved approximately 1225 ship calls in 2005 and 1285 in 2006.

The ship arrival rate was 0.168 ships/hour in 2005 and 0.176 in 2006. Total throughput during the considering period was 1704173 TEU in 2005 and 1703662 TEU in 2006. Also, the berthing/unberthing time of ships was assumed to be 1 hour. The ships were categorized into the following three classes according to the number of lifts: under 500 lifts; 501 – 1,000 lifts; and over 1,000 lifts per ship. Ship arrival probabilities were as follows: 24% for first class, 40% for second and 36% for third class of ships in 2005 and 30% for first class, 38% for second and 32% for third class of ships in 2006 [8].

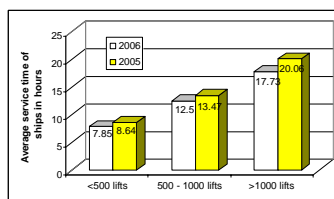


FIGURE 13  
Average service time of ships

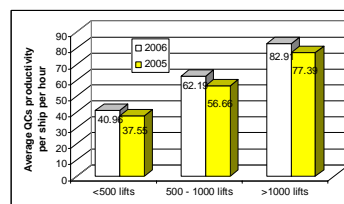


FIGURE 14  
Average QCs productivity

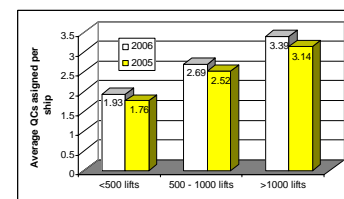


FIGURE 15  
QCs assigned per ship

Container terminals in Busan Port, especially PECT, are trying to expand capacity and increase performance at a maximum of investments. Often the container terminal operations are changing to meet increased customer demands as well as to adapt to new technologies. Reasons for the decrease of the average cost per ship served with the introduction of new container berth, QCs, container yard area and automated stacking cranes (ASC) include that waiting time of ships and the average time that ships spend in port decrease with the advanced handling systems improving the operations procedures (see results from Figures 13, 14 and 15) [6, 7 and 8]. A complete description of the simulation and analytical models is provided in [8].

## 5. CONCLUSIONS

Containerization continues to grow as it has done for a long time. While the entire world merchant fleet grew by only 1%, the containership fleet expanded by more than 10% and this continuous growth has also led to the development of very large containerships. Numerous studies indicate that mega container ship construction is not only feasible but may be a necessary development if this market expansion is to be accommodated in the most cost effective manner. After deploying above 12000+ TEU ships, how should ocean carriers reorganize the shipping network design? Will the bigger vessels lead to a reduction in port calls and how will the terminal operators respond? The impact of next generation ships on shipping lines and container terminals is examined.

The challenges facing the shipowner and the port operator are certainly real. But, it may be concluded that container shipping technology has undergone changes mainly in the scale of ships and terminals used but very little change in the technology itself. Changes in containership technology will probably not occur in the next 5 years, but radical changes in port, terminal and feeder operations must be expected to happen soon. The objective of most changes will be to: Reduce transshipment handling cost; Reduce mainline and feeder vessel turnaround times at transshipment and other terminals; Introduce driverless automated guided vehicles and continuous container conveyers; Introduce floating yard barges for containers; Introduce large outreach gantries spanning mainline and feeder vessels.

The liner shipping and port industry has been reshaped by logistic integration, containerization, deregulation and globalization. Liner shipping companies and container terminal operators have become the most important part in the international supply chains, which are complex and logistics models. The evolution in supply chains and logistics models urges liner shipping and container terminals to reconsider their function in the logistics process described with the trends in mega ships and mega container cranes in ports. These performances require the new ideas and concepts in container terminal planning in order to keep pace with the development of the mega container vessels.

The trend towards globalization of trade, together with the uncoupling of production sites and markets, has significantly increased the demand for containerized marine shipping. Due to the increased volume of container traffic and especially the sizes of container ships, container terminals have become important components of sea and logistics networks. These terminals serve as hubs for the transshipment of containerized goods from ship to ship or from ship to other modes of transportation, e.g., rail and trucks.

The face of the container shipping industry continues to change. Timing of introduction of new generations of container ships is very difficult. However, an attempt has been made for the next few years. The trend towards larger containerships also makes it more difficult to choose between hub port and feeder port strategies. This trend is driven by the continued growth in container shipping and increased deployment of mega-ships on major trade routes. The time-sensitive operating practices of such mega-ships mean that they require full loading capacity so that they can efficiently call at major hub ports with minimal dwelling time. By identifying demand growth, and making an assumption as to the market share of further demand could be approved by these ships, a range of possible fleet development can be estimated.

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# A HOLISTIC FRAMEWORK FOR PERFORMANCE MEASUREMENT IN LOGISTICS MANAGEMENT

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**Abstract** -The purpose of this paper is to introduce and describe an approach to performance measurement of logistics processes. The paper has four main parts. First, an introduction to logistics processes is provided. Then, the key performance indicators of the logistics processes are outlined. Third, a new improvement oriented performance measurement framework of logistics is presented. The originality/value of this paper is that it uses balanced objective matrix methodology (BOMAX) for examining key issues of logistics performance measurement at multiple levels within the organization. In this manner this article presents a comprehensive framework in constructing a strategic performance measurement system of logistic processes. It provides a multi-perspective approach which is more focused on the alignment of performance measurement framework of logistics process with company strategies and addresses the consolidation issue of these multiple viewpoints in a single, consolidated value.

**Keywords-** Performance Measurement, Logistics and Supply Chain Management,

## 1. INTRODUCTION

Nowadays logistics is seen as a value-adding process that directly supports the primary goal of the enterprise, which is to be competitive in terms of a high level of customer service, competitive price and quality, and flexibility in response to market demands. During the last decade logistics has gained much attention in increasing efficiency and flexibility of organizations as logistic costs make up a significant part of total production costs. The entire logistic process, from the acquisition of raw materials to the distribution of end-customer products, makes up a logistic chain consisting of multiple actors. Logistic activities within an enterprise can be divided into; -feed-forward flow of goods, including transportation, material handling and transformation (manufacturing, assembly, packaging, etc.); -feed-back flow of information, including information exchange regarding orders, deliveries, transportation, etc., and ; -management and control, including purchasing, marketing, forecasting, inventory management, planning, sales and after-sales service.

Stevens [1] defines a logistic chain as a system whose constituent parts include suppliers of materials, production facilities, distribution services and customers, all linked together via the feed-forward flow of materials and the feed-back flow of information. All these logistic processes are performed by using resources in the form of equipment, manpower, facilities and financial assets. In order to have a value-adding logistics process that directly supports the primary goal of the enterprise, which is competitive, an organization must position its basic strategic elements and core competencies of logistics process to adjust rapidly to critical changes in the environment. That ability implies that the organization has a measurement system in place for reviewing frequently the strategic performance of its logistics process. In this respect strategic performance management and measurement is critical to the success of any organization and needs to reflect the aims and the strategies of an organization that have been developed to achieve those aims. Through performance measurement systems managers can be able to encapsulate and 'take hold of' information about strategy, core competencies and future competitive ambitions of its logistic process in a tangible way. This includes monitoring results, comparing to benchmarks and best practices, evaluating the efficacy and efficiency of the logistics process, controlling for variances, and making adjustments as necessary. With sufficient and carefully selected information provided by performance measurement systems, it becomes possible for companies to understand better what is going on and what is about to happen in logistics. It is important to realize that what is not understood cannot be managed. Managers need clear, timely and relevant signals from their internal information systems to understand root causes or problems in logistics process, to initiate correction action, and to support decisions at all levels of the organizations. Therefore a new measurement concept is needed which is consistent and compatible with this process perspective. This study provides new insight into understanding the success and hindering factors of logistics management. The extensive literature

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review and case studies provide academics and managers a macro picture of the goals, challenges, and strategies for implementing an effective logistics management and performance measurement.

## 2. THE PROCESS VIEW IN LOGISTICS AND SUPPLY CHAIN MANAGEMENT

Process view is one of the key elements in logistics and supply chain management. According to Christopher [2]: Logistics is a process of strategically managing the procurement, movement and storage of materials, parts and finished inventory (and the related information flows) through the organization and its marketing channels in such a way that current and future profitability are maximized through the cost-effective fulfillment of orders. Andersen [3] has argued that several issues have stressed the logic of the transition from viewing the company as a number of departments to focusing on the business processes being performed:

- \_\_Every process has a customer, and focusing on the process ensures better focus on the customer.
- \_\_The value creation with regard to the end product takes place in horizontal processes.
- \_\_By defining process boundaries and the customers and suppliers of the processes, better communication and well-understood requirements can be achieved.
- \_\_By managing entire processes that run through many departments rather than managing individual departments, the risk of sub optimization is reduced.
- \_\_By appointing so-called process owners, who are responsible for the process, the traditional fragmentation of responsibility often seen in a functional organization is avoided.
- \_\_Managing processes provides a better foundation for controlling time and resources.

Many of these elements are based on the fact that every single process has both a supplier and a customer. A main point is that any business process has a customer, either external or internal. Based on this definition, almost all activities within a company can be seen as a business process or part of a business process, including the processes related to logistics. Performance measurement of logistics describes the feedback or information on logistics activities with respect to meeting customer expectations and strategic objectives. Performance measurement systems should answer two simple questions [4]

- a. Are functions and departments doing the right things?
- b. Are they doing them well?

Performance measures are used to measure and improve the efficiency and the quality of the logistics processes, and identify opportunities for progressive improvements in logistics process performance. Traditional measures, however, are usually ineffective barometers of performance because they do not isolate non-value-added costs. In addition, most measures overlook key non-financial performance indicators [4]. Performance measures are classified in several ways in the literature. When describing and measuring the performance level in a business process, a number of parameters might be used. It is pivotal to employ a balanced set of measures in order to understand the performance of the process and be able to identify improvement areas. Typical dimensions for describing and measuring performance are [5]:

- \_\_Qualitative and quantitative measures.
- \_\_‘Hard’ versus ‘soft’ measures.
- \_\_Financial versus non-financial measures.
- \_\_Result versus process measures.
- \_\_Measures defined by their purpose (result, diagnostic, and competence).
- \_\_Efficiency, effectiveness, and changeability.
- \_\_The six classic measures (cost, time, quality, flexibility, environment, and ethics).

All areas should be considered when developing performance measures. It should be emphasized that these dimensions overlap. In order to diagnose the ‘health status’ of an organization one should ideally employ a balanced combination of measures. Fagerhaug [5] has developed a criteria sheet. The sheet provides the name and a short description of the process/structure, as well as a number of text-based and number-based measures belonging to each of the five categories mentioned above. Based on this criteria sheet the author of this paper would argue that a number of measures could be used to enhance the performance of the logistics processes (Table 1). As listed in Table 1, several concrete measures are introduced to show how logistics process performance can be measured in practice. It should be emphasized that the measures are examples rather than a final set.

Different measures are needed in different levels of organization. There should be information available for strategic management purposes at the company level. On the other hand, information is needed also for

operational management at the work shop level. Measures can be used mainly on three levels. Firstly, logistics companies can analyze general environment and their own performance at company level. These measures are global in nature, covering a wide scope of activities. Global measures provide top management with a sense of whether strategic objectives are being achieved. They are monitored month-to-month or quarter-to-quarter. In a sense they keep management in touch with the outside world. Secondly, they can measure individual projects' performance. Finally, they can focus on processes and departments. These types of measures are more specific to the internal workflow. They represent day-to-day measures of operating effectiveness and efficiency [4]. It is better for a small company to pick only a couple of measures and start with them. This means that they can find out the current performance and improvement potential of the firm.

### **3. THE INTEGRATION OF OBJECTIVE MATRIX (OMAX): AN APPROACH IN DETERMINING THE PARTIAL AND OVERALL PERFORMANCE INDEXES OF LOGISTICS PROCESS - THE BALANCED OMAX (BOMAX)**

Productivity in a narrow sense has been measured for several years. In 1978 an enlarged method, the POSPAK method, was introduced. This method indicates specific measures in order to improve the overall productivity of an enterprise [6]. One of the first approaches to performance measurement was published by Sink and Tuttle [7]. The model claimed that the performance of an organizational system is a complex interrelationship between seven criteria. In 1993 Hronec [8] published the book 'Vital Signs', where he described how to use quality, time, and cost performance measurements to chart the company's future. In 1995 Rolstadås [9] edited the book 'Performance Management'. It sought to provide the reader with a detailed overview of the modern enterprise by focusing on performance evaluation and measurement and performance improvement techniques. Since 1995 a number of books and papers on performance measurement and management have been published. An example of one of these published materials is the so called BOMAX performance measurement system, which was developed by the researcher self [10]. Through performance measurement, the various performance level of the business should be monitored. Based on this business model, BOMAX has suggested three levels of hierarchy for defining performance indicators. Each performance indicator is a function of two or more performance measures. The three levels of hierarchy for defining performance indicators are: 'Enterprise Level', 'Process Level' and 'Functional Level'. BOMAX emphasize that the self-assessment process allows the organization to discern clearly its strengths and areas in which improvements can be made and culminates in planned improvement actions which are then monitored for progress. Based on the self-assessment, improvement planning should be performed and initiated. As shown in the figure, performance measurement provides input for the improvement planning, choice of improvement tools, as well as for the self-assessment process. As it was mentioned the chapter before, there is needed a method of indexing performance measures, and calculating an overall, multi-factor, performance index. Several techniques are available for this purpose. The thesis of this article is that the BSC [11] and OMAX [12]. Philosophies complement each other quite effectively. BOMAX is one of the few techniques capable of integrating the whole gamut of strategic measures into a single coherent summary as a consolidated value. Had OMAX alone been used, a manager would have trouble making tradeoffs among alternative strategic objectives. In contrast, had the BSC alone been used, the connection between financial and non-financial criteria would have been less robust. By integrating both OMAX and the BSC, the organizations could be able to create synergies which overcame the weaknesses of the individual methodologies. By combining the strengths of the two, we end up with a stronger, more robust framework with increased predictive power, the so-called 'Balanced Objective Matrix (BOMAX).' Through BOMAX method performance measures are normalized and an overall, multi-factor performance index is calculated. An index is a composite number that is created by mathematically combining several individual measures. While concentrating just on only one strategic performance index simplifying the decision making of managers and avoiding the confusion caused by dealing with many performance indicators at once which usually yields only a vague general perception. The single number resulting from the BOMAX will tell management if the organization's strategic performance qualifies as excellent, unsatisfactory or just mediocre. This single index is the indicator of how well the organization is doing against the preset target or evaluated along with other measures. The four main components of BOMAX are: the performance measures of each of the logistics processes (the scaled KPI) ( $M_i$ ), the weights ( $w_i$ ), the performance scale ( $L_i$ ), and the performance index ( $PI_i$ ).

Logistics Processes	BSC Perspectives –Key Performance Indicators (KPI)									
	Learning-Growth		Internal Process			Customer Satisfaction		Financial		
Warehousing receiving, put-away, replenishment, cycle-counting, picking, packing, shipping, kitting, returns	M <sub>L,1</sub>	M <sub>L,1</sub> ,....., M <sub>L,n</sub> Commitment /Staff	M <sub>P,1</sub>	Packaged pcs/year	M <sub>C,1</sub>	M <sub>C,1</sub> ,....., M <sub>C,n</sub> Failure/essness (failure rate)	M <sub>F,1</sub>	M <sub>F,1</sub> ,....., M <sub>F,n</sub> Pers. Costs/ commitment		
			M <sub>P,2</sub>	Utilization of loading surface (%)	M <sub>C,2</sub>	Pollteness	M <sub>F,2</sub>	Pers.costs/Volume, unit, value		
			M <sub>P,3</sub>	Utilization of loading space (%)	M <sub>C,3</sub>	Reliability	M <sub>F,3</sub>	Construction and op.costs/Year		
			M <sub>P,4</sub>	Vol loaded in/out/Staff	M <sub>C,4</sub>	Advising	M <sub>F,4</sub>	Managing costs/commitment		
	M <sub>L,2</sub>	Man-facilities relation (ergonomy, environment ,protection)	M <sub>P,4</sub>	Vol loaded in/out/Staff	M <sub>C,4</sub>	Advising	M <sub>F,4</sub>	Managing costs/commitment		
M <sub>L,3</sub>	Optimum combination of jobs (tasks) and facilities	M <sub>P,5</sub>	Packaged pcs/staff	M <sub>C,5</sub>	Quick response on complaints	M <sub>F,5</sub>	Total man.costs/total warehouse cost			
Inventory turns, safety-stock, cycle-stock, transit-stock, strategic-stock, replenishment frequency, consignment-stock	M <sub>L,4</sub>	Optimum combination of jobs (tasks) and facilities	M <sub>P,6</sub>	Handled volume/Staff	M <sub>C,6</sub>	Damage events/total activities	M <sub>F,6</sub>	Stor.,pack., handl., costs/volume, unit, value		
			M <sub>P,7</sub>	Handled volume/year						
			M <sub>P,8</sub>	Physical performance time/Processing time						
			M <sub>P,9</sub>	Av.inventory (volume, value)	M <sub>C,7</sub>	Restorability (av.restoring time, total break-down time)	M <sub>F,7</sub>	Pers. Costs/commitment		
	M <sub>L,5</sub>	Commitment Staff	M <sub>P,10</sub>	Av.storage time (day, hour, minute)	M <sub>C,8</sub>	Pollteness	M <sub>F,8</sub>	Pers.costs/ Volume, unit, value		
		M <sub>P,11</sub>	Av. Inventory efficiency (day, minute)	M <sub>C,9</sub>	Reliability	M <sub>F,9</sub>	Construction and op.costs /Year			
		M <sub>P,12</sub>	Rotation frequency /year	M <sub>C,10</sub>	Advising	M <sub>F,10</sub>	Interest/ Volume, unit, value			
		M <sub>P,13</sub>	Commitments/year	M <sub>C,11</sub>	Quick response on complaints	M <sub>F,11</sub>	Total stor.&inv.costs/total log costs			
		M <sub>P,14</sub>	Average time of comm.(hour, minute)							
Transportation rating, routing, tracing and tracking, sourcing, auditing and payment, management	M <sub>L,5</sub>	Commitment /staff	M <sub>P,15</sub>	Tr.ed volume/ Staff	M <sub>C,12</sub>	Restorability (av.restoring time, total break-down time)	M <sub>F,12</sub>	Total tr. Costs/total log.costs		
			M <sub>P,16</sub>	No of transports/year	M <sub>C,13</sub>	Pollteness	M <sub>F,13</sub>	Tr.costs/volume, tkm, km		
			M <sub>P,17</sub>	Ton km/Vehicle and year	M <sub>C,14</sub>	Reliability	M <sub>F,14</sub>	Tr.cost/time&vehicle		
			M <sub>P,18</sub>	Av.Vol.Transport/ Av.time. Transport	M <sub>C,15</sub>	Trucking&tracing	M <sub>F,15</sub>	Tr.costs/commitment		
			M <sub>P,19</sub>	Average distance (km)	M <sub>C,16</sub>	Quick response on complaints				
		M <sub>P,20</sub>	Utilization of vehicles(%) related to time, load capacity and tkm	M <sub>C,17</sub>	Damage events/total activities					
		M <sub>P,21</sub>	Error delivery/total delivery commitments							

Table 1: Key Performance Measures of Logistics Process in respect to BSC

The top row of the matrix includes the KPI which are assessed by BSC approach and defined for each BSC perspectives. The perspectives and their abbreviations are Learning and Growth (L); Finance (F); Customer-Citizen (C) and Internal Process (I). In BOMAX methodology dissimilar measures can be compared, and combined to produce an overall-global performance index. In order to be able to compare dissimilar measures, to see the inter-relationships between them, it is possible to index the measures scores, and so convert them to the same scale. The middle section holds eleven rows with different outcomes for the specific performance measures. These rows are ranked or scaled from zero to ten. The index scale is created by establishing a target value for each performance measure based on their current performance. The bottom of the target range is defined as the minimum level that can be permitted. Matching the levels of performances with the level of the rows in a way that an outcome of ten will be the most desirable and zero the least desirable and typical outcomes of each indicator are aligned with a score of three. The initial baseline called the 'as is' performance level for each performance measure is determined and assigned to level 3. The scaling should be conducted in the way that grade 10 could be achieved with excellent performance at least in five years time horizon. That means the time horizon should be defined in BOMAX very carefully and can typically be about a year or less for short-term goals or spans several years for long-term goals. The possible outcomes-the intermediate values- of the performance measures are found in the body of the matrix and are calculated for scores between these ranges ( $L_i$ ). The objective of these arrangements prevents the awarding of high grades to mediocre or normal performance, and embraces the notion of stretching the work force to a superior performance and betterment of the system. Ranks in the matrix's body should be clearly marked so they do not provide a margin of doubt when assigning a score. The bottom of the matrix weights the categories for the aggregation process. For each BSC perspective measures on BOMAX weighted according to their importance that is felt would create the biggest challenge in terms of achieving the strategic targets. These weights are determined by management and add up to one hundred. The score in each column is multiplied by the weight, producing a final number or 'index' that represents the 'grade' of the strategic activities for that specific period ( $PI_i$ ). Performance indexes are not an exact measure of achievement but rather provide an indication of business performance. To be useful, performance indexes must exhibit certain characteristics: appropriateness, relevance, accuracy, timeliness, completeness and comprehensiveness. When indexes begin to move outside the threshold limits, the performance measurement system can alert management, who then attempt to diagnose the problem and address its causes. The development of performance indexes is not an end in itself but rather one part of a structure of governance and accountability. They can indicate whether strategic planning has been undertaken and is well focused on the reason for the organization existing. This method of monitoring the strategic measures enables to identify the current levels of strategic performance, and where action is needed to improve them. It will provide feedback of the effects of the actions, and ensure that the strategic performance continually improves. The BOMAX can be interpreted separately in three different ways: each performance measure as an unit, the performance sub-index as an index of a BSC perspective and lastly as a sum up measure off all BSC categories pulled together in one final index as departmental and company level (Figure 1). BOMAX provide insight into different departments or levels of analysis. Most help desks have various sub sections like front desk and solution providers, etc., which all contributing to overall success of a help desk. The proposed framework, allow managers to do just that. To gauge exactly how well a section in a help desk is performing the overall performance index will allow the managers to capture and report specific data points from each section within the organization providing a 'snapshot' of performance. Performance Index of each Logistics Process (PPI) of each in respect of BSC perspectives at period t (Eq.1);

$$PPI_{\alpha(t)} = \frac{\sum_{i=1, \dots, n} L_{Gi} \cdot w_{Gi} + \sum_{i=1, \dots, n} L_{Pi} \cdot w_{Pi} + \sum_{i=1, \dots, n} L_{Ci} \cdot w_{Ci} + \sum_{i=1, \dots, n} L_{Fi} \cdot w_{Fi}}{PPI_{\alpha(t-1)}} \dots \dots \dots (1)$$

$i=1, \dots, n$  number of measures,  $j=1, \dots, m$  number of logistics processes  $M_i$ =Performance measures  $L_i$  = Performance scales of  $M_i$   
 $x_{ij}$ =The current values of measures( $M_i$ )  $w_i$ = weights of measures

$$\sum_{i=1, \dots, n} w_i = 100\%$$

CRITICAL SUCCESS FACTORS (CSF <sub>1</sub> ,.....CSF <sub>IN</sub> )												
Performance Measure	Learning&Growth			Internal Process			Customer			Finance		
	M <sub>L1</sub>	.....	M <sub>Ln</sub>	M <sub>P1</sub>	.....	M <sub>Pn</sub>	M <sub>C1</sub>	.....	M <sub>Cn</sub>	M <sub>F1</sub>	.....	M <sub>Fn</sub>
	X <sub>L1</sub>	....	X <sub>Ln</sub>	X <sub>P1</sub>	.....	X <sub>Pn</sub>	X <sub>C1</sub>	.....	X <sub>Cn</sub>	X <sub>F1</sub>	.....	X <sub>Fn</sub>
Actual value												
10	L <sub>10</sub>											
9	L <sub>9</sub>											
8	L <sub>8</sub>											
7	L <sub>7</sub>											
6	L <sub>6</sub>											
5	L <sub>5</sub>											
4	L <sub>4</sub>											
3	L <sub>3</sub>											
2	L <sub>2</sub>											
1	L <sub>1</sub>											
0	L <sub>0</sub>											
Level Weight	L <sub>L1</sub>	...	L <sub>Ln</sub>	L <sub>P1</sub>	...	L <sub>Pn</sub>	L <sub>C1</sub>	...	L <sub>Cn</sub>	L <sub>F1</sub>	...	L <sub>Fn</sub>
Σw <sub>i</sub> =100%	w <sub>L1</sub>	....	w <sub>Ln</sub>	w <sub>P1</sub>	....	w <sub>Pn</sub>	w <sub>C1</sub>	....	w <sub>Cn</sub>	w <sub>F1</sub>	....	w <sub>Fn</sub>
Performance Value	L <sub>L1</sub> ·w <sub>L1</sub>	.....	L <sub>L1</sub> ·w <sub>Ln</sub>	L <sub>P1</sub> ·w <sub>P1</sub>	.....	L <sub>Pn</sub> ·w <sub>Pn</sub>	L <sub>C1</sub> ·w <sub>C1</sub>	.....	L <sub>Cn</sub> ·w <sub>Cn</sub>	L <sub>F1</sub> ·w <sub>F1</sub>	.....	L <sub>Fn</sub> ·w <sub>Fn</sub>

FIGURE 1: THE DEPARTMENTAL BOMAX OF A HELP DESK

#### 4. CONCLUSION

This paper has sought to give an introduction to a new approach for measuring and improving performance of logistics processes. In order to describe the approach, an introduction has been given to performance measurement. A performance improvement framework has also been introduced. This method can be employed at certain intervals, for instance annually may also be used for short periods of time. The developed performance measurement systems are both focused on the results and the processes of logistics. We would argue that the use of the approach would enhance the performance of logistics processes.

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# HEURISTICS FOR A GENERALIZATION OF TSP IN THE CONTEXT OF PCB ASSEMBLY

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**Abstract** — *Traveling Salesman Problem (TSP) is one of the most well-known NP-Hard combinatorial optimization problems. Adding new constraints to the problem yields different generalizations to the problem and each new generalization forms the basis of a new research area. In this study, we propose new techniques for a generalization of the TSP. In this problem, the cost of traveling between two cities does not only depend on the distance between these cities, but also on the visiting sequence. We analyzed the problem under different conditions; the first and last points (nodes) are set fixed or they are free and for solving the problem we propose several heuristics. After analyzing constructive heuristics, improvement heuristics are applied. As improvement heuristics, we implemented pair-wise exchange procedure (PEP) and record-to-record travel with local exchange moves (RTRLEM). Comparison of these approaches together with their parameter fine tuning are given.*

**Keywords** — *Heuristic, printed circuit board, sequence, traveling salesman problem*

## INTRODUCTION

Traveling Salesman Problem (TSP) is one of the most well-known NP-Hard combinatorial optimization problems. Adding new constraints to the problem yields different generalizations to the problem and each new generalization forms the basis of a new research area. Mostly known generalizations are Asymmetric TSP, Vehicle Routing Problem (VRP) and its variants. TSP is observed in many research areas and among these we can easily pronounce logistics and transportation. After a small survey on TSP, one can easily argue that there is uncountable number of studies towards solving it since it is introduced to the literature, ranging back to at least the late 1940's. The TSP is the focus of interest for many research disciplines (mostly computer scientists and mathematicians) because, even after about half a century of research, the problem has not been completely solved. This is because any programmable efforts to solve such problems would grow super-polynomially with the problem size. These categories of problems became known as NP-hard [1].

We observe the spirit of the traveling salesman problem within many practical applications in real life. For example, a mail delivery person tries to figure out the most optimal route that will cover all of his/her daily stops, a network architect tries to design the most efficient ring topology that will connect hundreds of computers, a manufacturing engineer tries to design the shortest sequence for assembling components on a printed circuit board (PCB). In all of these instances, the cost or distance between each location, whether it be a city, building or node in a network, is known (we use the terms "vertex", "node" and "point" interchangeably in this study). With this information, the basic goal is to find the optimal tour.

In this study, we analyze a generalization of TSP in which, the cost of traveling between two cities does not only depend on the distance between these cities, but also on the visiting sequence. This problem is observed in PCB assembly machine optimization. We firstly define the problem, and then propose some heuristics for solving the problem. The performance analyses of the proposed heuristics are also done within the study.

In the next section, classical TSP definition and formulation is given together with a literature survey of proposed techniques and heuristics towards optimizing it. Also definition of the generalization of the TSP is given. The constraints to the problem are given with its definition. In the following section, proposed solution heuristics are defined in detail. The proposed heuristics are compared on randomly generated PCB data and the results are given in Results and Discussion section which is followed by a conclusion.

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## PROBLEM DEFINITION, CONSTRAINTS AND LITERATURE SURVEY

The TSP is stated as, given a complete graph,  $G=(V,E)$ , where  $V$  is a set of vertices,  $E$  is a set of edges, and a cost,  $c_{ij}$ , associated with each edge in  $E$ . The value  $c_{ij}$  is the cost for travelling from vertex  $i \in V$  to vertex  $j \in V$ . Cardinality of  $V$  is denoted by  $n$ , i.e.  $|V|=n$ . Given this information, a solution to the TSP must return the cheapest Hamiltonian cycle of  $G$ . A Hamiltonian cycle is a cycle in which each vertex in a graph is visited exactly once.

In order to obtain a solution to TSP, several solution methodologies are developed. Exact algorithms are guaranteed to find an optimal solution and to prove its optimality for every instance of a class of combinatorial optimization problems. The run-time, however, often increases dramatically with the instance size, and often only small or moderately sized instances can be practically solved to provable optimality. We can categorize the exact algorithms as branch-and-bound, cutting planes and branch-and-cut [2]-[4].

Another approach for solving TSP-like problems is developing heuristic methods. In heuristic methods we sacrifice the guarantee of finding optimal solutions for the sake of getting good solutions in a significantly reduced amount of time. Among the basic heuristic methods we usually distinguish between constructive methods and local search methods. Constructive algorithms generate solutions from scratch by adding—to an initially empty partial solution—components, until a solution is complete. They are typically the fastest heuristic methods, yet they often return solutions of inferior quality when compared to local search algorithms. Local search algorithms start from some initial solution and iteratively try to replace the current solution by a better solution in an appropriately defined neighborhood of the current solution.

Among the constructive methods developed for TSP we can list Convex-Hull and Nearest Neighbor algorithms [5]-[7]. Several local search methods are also developed for TSP. Croes developed first 2-opt algorithm, not after a decade Lin generalized the 2-opt concept to  $r$ -opt [8]-[9]. Or developed Or-Opt algorithm where he relocates chains of length three, two and one [6]. Recently, Babin et al. showed that improved Or-Opt + 2-opt is an excellent combination and is easy to implement [10]. All of these local search methods put promising results for reaching optimality in a reasonable time. For a complete survey and summary about TSP, we direct the reader to [7].

### A generalization of the TSP

In this study, we deal with problem which is a generalization of the TSP. In classical TSP, the cost between two points is fixed and known a priori. Thus the cost function,  $CI(x,y)$ , implies that the cost increase linearly with distance,  $d(x,y)$  (3). The distance may be either Euclidean or Chebyshev metric. In Euclidean metric, the distance is directly calculated by the formula

$$d(x, y) = \sqrt{(x_1 - y_1)^2 + (x_2 - y_2)^2} \quad (1)$$

whereas in Chebyshev metric the distance is calculated by using

$$d(x, y) = \max\{|x_1 - y_1|, |x_2 - y_2|\}. \quad (2)$$

Chebyshev metric is usually encountered in placement machines. In this study, we calculate cost in time units, so we define  $CI(x,y)$  mathematically as follows:

$$CI(x, y) = \frac{d(x, y)}{v} \quad (3)$$

where  $v$  is a predefined constant.

However, in our problem the cost of travel between cities depends also on the visiting sequence and some other predefined parameters. We face this generalization of TSP while optimizing the operations of a component placement machine in PCB manufacturing industry [11]. Nevertheless, as we pointed out before, TSP and its variants can be observed in a number of cases in real life, and we believe that optimization techniques developed for this type of problem can be applied in other research areas.

In this generalization of TSP, the cost function is stated as

$$C2(t_i, x, y) = \max\{t_i, CI(x, y)\} \quad (4)$$

Observe that this function is dependent on a parameter  $t_i$  and it is known at compile time.

What makes the problem complicated is that there are a number of  $t_i$  values and they are used in different positions of the placement sequence. In our case, there are four different  $t_i$  values and  $t_1 < t_2 < t_3 < t_4$ . In order to explain the usage of  $t_i$  values assume that a tour is already created. Then total travel cost is calculated as

follows. Starting from the first point on the tour (depot), cost of travel for  $n_1$  points is calculated by using  $C2(t_1, x, y)$ . Cost for following  $n_2$  points on the tour is calculated by using  $C2(t_2, x, y)$  and so on where  $\sum_{i=1}^4 n_i = n$  and they are given as input to the problem.

For optimizing this problem, we developed several heuristics. Since the problem is a generalization of TSP, any solution obtained by using algorithms proposed for TSP is feasible for it. Hence, algorithms proposed for classical TSP can be used for reaching initial solutions to the problem. Specifically, we applied Convex-Hull and Or-Opt algorithms [5]-[6]. But we should note that while applying these algorithms,  $C1(x, y)$  is used as the cost function because applying  $C2(t_i, x, y)$  is impractical (actually, that's why the problem is a hard problem to attack).

### Constraints to the problem

In some environments where the generalization of TSP is encountered, adjusting the starting (first) point, (depot), of the tour may be impossible. For example, for a firm distributing goods from a depot, the depot is predetermined and moving it to a new location may have a large cost. Also, the tour is generally expected to end when the salesman returns back to depot but, in some cases the ending (last) point may be another point different from the first point. Consider a salesman starting the tour from the firm and is planning to finish the tour by his/her home.

In PCB assembly machines, mostly neither of these requirements exists. So, the manufacturing engineer is free to select a first point. The tour is completed when the first point is reached, and at that moment assembly of another PCB starts. For a complete study, we will analyze the problem under each constraint separately. So, there exist three cases.

Case 1: Fixed first point (FP) and the tour is completed when the salesman returns to FP

Case 2: Fixed FP and fixed last point (LP)

Case 3: Free selection of FP

## SOLUTION METHODOLOGIES

### Proposed Local Search Heuristics

In this study, we used Convex-Hull and Or-Opt to obtain an initial solution to the problem. The performances of the Convex-Hull and the Or-Opt procedures are analyzed by many researchers in the literature regarding Chebyshev distance measure. It was shown that, solution procedures similar to Or-Opt are very successful [12]. This is the main reason why these algorithms are used for an initial solution.

As stated in previous sections, obtaining new solutions from an initial current solution requires a local search. In TSP variants, for a local search a general method is to apply exchanges of edges or nodes [8],[13]. For exchanging two nodes, two alternatives exist; we can either insert a node into a different place on the route, called 1-0 Exchange move, or we can exchange two nodes, called 1-1 Exchange. Exchanging two edges is called 2-Opt move.

In order to improve the algorithms, we designed two local search heuristics. First one is a local random search procedure. The procedure starts with a given solution and applies a number of pair-wise (1-1) exchanges. Therefore we call it pair-wise exchange procedure (PEP). More specifically, it can be defined as follows. Randomly determine two points (components). If the new cost stays the same or decreases by exchanging these two points, perform the exchange. Continue this procedure until a predetermined number of exchange trials are made.

The other heuristic developed is a hybrid of record-to-record travel (RRT) and local search moves. RRT is a deterministic variant of Simulated Annealing (SA), developed by Dueck and it is shown that the quality of the computational results obtained so far by RRT is better than SA [14]. In RRT *Record* is defined as the cost of best solution observed so far. *Deviation* is defined as a predefined percentage of *Record*. It is deterministic because, a neighbor solution  $s'$  replaces current solution only if its cost is less than  $Record + Deviation$ .

We developed an improvement algorithm that combines RRT with local search moves. We call it RRT with local exchange moves (RRTLEM). It is a general framework that consists of simple iterative statements (Figure 1). How RRT concept is embedded in 1-0 local search move is given in Figure 2 as an example.

```

Create neighbor list, NL(i) for each node i.
cs := Create initial solution using Convex-Hull and Or-Opt
for a predefined number of times
  apply 1-0 Exchange move with RRT (uphill moves allowed)
  apply 1-1 Exchange move with RRT (uphill moves allowed)
  apply 2-Opt Exchange move with RRT (uphill moves allowed)
endfor
cs := bs
apply 1-0 Exchange move with RRT (only downhill moves)
apply 1-1 Exchange move with RRT (only downhill moves)
apply 2-Opt Exchange move with RRT (only downhill moves)

```

FIGURE 1

RRT with Local Exchange Moves (RRTLLEM)

```

for each node i in the current solution cs
  savings := -∞
  for each edge j whose one end is in NL(i)
    obtain s' by inserting node i between edge j
    if f(s') < f(cs)
      cs := s'
      if f(s') <= f(bs)
        bs := s', dev := f(bs) x rate
      endif
      continue with the next node
    endif
  endfor
  if f(s') >= f(s) and f(s) - f(s') >= savings
    store j as maximum saving edge (mes := j)
  endif
endfor
if f(s) - savings <= f(bs) + dev and uphill moves allowed
  cs := the solution obtained by inserting node i between mes
endif
endfor

```

FIGURE 2

1-0 Exchange move with RRT

The idea is inspired from the study [15], but important modifications are added that will improve the performance. PEP and RRTLLEM are improvement heuristics that can be applied in any of the cases. From the implementer's point of view, PEP is a straightforward algorithm to implement while RRTLLEM requires use of complicated data structures and much more care.

### Proposed Heuristics for Case 2 (Fixed FP and LP)

For case 2, where FP and LP is fixed, we propose two heuristics. Before explaining the details of these heuristics, let us visualize the case by an example. Assume that the tour starts by the point FP. The tour is expected to end with LP but Convex-Hull gives a complete tour that ends by FP. However, in this case some of the points (points between FP and LP) are excluded from the tour and this situation raises the question of how to deal with these excluded components. These components somehow must be inserted into the placement sequence. For inserting these components into the placement sequence, we developed Least Cost Insertion (LCI) and Group Insertion (GI) heuristics. In LCI, each excluded vertex is included between vertices where the total cost increases minimum.

Other method for inserting these excluded points can be defined as follows. In the tour formed by Convex-Hull Or-Opt the points between FP and LP are separated from the tour by preserving the order determined by Convex-Hull Or-Opt. Then insert this group of points between points  $i$  and  $j$  in the tour that gives the minimum total cost (total assembly time). In each insertion trial, both normal and the reverse order of the group are considered. This approach for inserting the excluded points is called Group Insertion (GI) in the following discussions.

### Proposed Heuristic for Case 3 (Free selection of FP)

In this study, we propose Adjusting First Point heuristic (AFP) for Case 3. The idea behind AFP is very simple. We firstly build an initial tour by using Convex-Hull and Or-Opt algorithms. Then for each point  $i$  in the tour, we modify the route such that the tour starts from point  $i$  and calculate new cost of the tour. At the end, the point that minimizes cost of the tour is chosen as the first point for the tour. AFP is only applicable when we are free to select first point of the tour.

### Application plan of proposed heuristics to cases

Each case has different constraints and therefore proposed heuristics may not be applicable to all three cases. Thus, we made an application plan of these heuristics. PEP and RRTLLEM are based on local exchange moves, so they are applicable to all cases.

TABLE 1  
Application plan of heuristics

Case	Heuristics applied
Case 1 (Fixed FP)	Convex-Hull and Or-Opt + PEP or RRTLLEM
Case 2 (Fixed FP and LP)	Convex-Hull and Or-Opt + LCI or GI + PEP or RRTLLEM
Case 3 (Free selection of FP)	Convex-Hull and Or-Opt + AFP + PEP or RRTLLEM

On the other hand, LCI and GI are based on inserting any excluded vertices in the tour. Hence they are designed for Case 2 and their application to other cases does not make any sense. Our last heuristic AFP is based on changing the starting point of the tour hence is applicable only in Case 3. Table 1 summarizes the application plan.

## RESULTS AND DISCUSSION

A data generator that produces random printed circuit boards is implemented. The methodology for this generator is the same as the one used by [11]. The total number of components to be placed,  $n$ , is set as 100. The board that these components are placed is assumed to have dimensions of 250mm by 300mm and it is assured that no two components can be placed on the same coordinate. The data generator generated 100 instances of PCB and they are kept in files as inputs for the algorithms. In this section, any value appearing in a comparison table is the average of these 100 PCBs, unless stated otherwise. The basic and most important comparison criterion in PCB placement machines is the total assembly time of a given PCB.

Parameters of the proposed heuristics are set as follows. PEP is based on (1-1) exchanges and number of exchanges is set as  $10^6$ . In our analysis we found that increasing the number of exchanges does not provide much performance in terms of total assembly cost, but results in much more cost in terms of running time. RRTLEM has two parameters that must be fine tuned in order to obtain best performance. These are the number of iterations, *noi*, and percentage value, *rate*, which is used to calculate the deviation. After an analysis, we decided on that *rate* parameter should be equal to 1.4% and *noi* parameter should be equal to 400.

In Table 2, we give the performance results of the heuristics that can be applicable to Case 1. Assembly time is the cost of tour, running time is the time for the computer to finish the heuristic (total time for 100 instances) and improvement ratio is obtained by comparing the assembly time of the heuristic by Convex-Hull and Or-Opt. We can say that RRTLEM shows best performance both in terms of running time and assembly time. PEP may be considered as an alternative when observed from the implementer's point of view.

TABLE 2  
Performance comparison of heuristics for case 1

Heuristic	Assembly Time (sec.)	Running Time (sec.)	Improvement Ratio
Convex-Hull Or-Opt	40.55	53	-
Convex-Hull Or-Opt + PEP	39.35	1802	2.97%
Convex-Hull Or-Opt + RRTLEM	38.63	1174	4.73%

In Table 3, the performance results of heuristics applied to Case 2 is summarized. We tried several alternatives and formed six heuristics. They are again compared with the performance of Convex-Hull and Or-Opt. We observe that applying only LCI or GI increases the performance only about 1.6% in about the same running time. We also observe that PEP cannot put much on the performance of LCI and GI performance when its running time cost is considered. On the other hand, RRTLEM achieves to increase the performance gain up to 5.00% with a running time equal to 2/3 of PEP.

TABLE 3  
Performance comparison of heuristics for case 2

Heuristic	Assembly Time (sec.)	Running Time (sec.)	Improvement Ratio
Convex-Hull Or-Opt	40.55	53	-
Convex-Hull Or-Opt + LCI	39.93	55	1.54%
Convex-Hull Or-Opt + GI	39.88	54	1.66%
Convex-Hull Or-Opt + LCI + PEP	39.70	1760	2.10%
Convex-Hull Or-Opt + LCI + RRTLEM	38.54	1186	4.97%
Convex-Hull Or-Opt + GI + PEP	39.46	1774	2.69%
Convex-Hull Or-Opt + GI + RRTLEM	38.52	1173	5.00%

When we analyze the results of Case 3, the results are more fascinating (Table 4). Applying only AFP brings 4.77% improvement almost in the same running time. Moreover, RRTLEM increases this value more than 6 per cent. This performance increase may be due to free selection of FP.

TABLE 4  
Performance comparison of heuristics for case 3

Heuristic	Assembly Time (sec.)	Running Time (sec.)	Improvement Ratio
Convex-Hull Or-Opt	40.55	53	-
Convex-Hull Or-Opt + AFP	38.62	54	4.77%
Convex-Hull Or-Opt + AFP + PEP	38.47	1752	5.13%
Convex-Hull Or-Opt + AFP + RRTLEM	37.97	1155	6.37%

## CONCLUSION

In this study, we analyzed a generalization of the well known combinatorial optimization problem TSP. In this problem, the cost of traveling between two cities does not depend only on the distance between these cities, but also, on the visiting sequence. This problem arises in optimization of PCB assembly machines. We analyzed the problem under several constraints and thus we categorized those under three titles. We proposed several heuristics for the problem where some of them are applicable only under certain conditions. The performance of the heuristics is compared on randomly generated PCB data. We can easily say that AFP algorithm together with RRTLEM shows best performance among all by a performance improvement of more than 6 per cent.

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# PREMIUM E-GROCERY: EXPLORING VALUE IN LOGISTICS INTEGRATED SERVICE SOLUTIONS<sup>1</sup>

Burçin BOZKAYA<sup>2</sup>, Ronan DE KERVENOAE<sup>3</sup> and D. Selcen Ö. AYKAÇ<sup>4</sup>

**Abstract** — *E-grocery is gradually becoming viable or a necessity for many families. Yet, most e-supermarkets are seen as providers of low value “staple” and bulky goods mainly. While each store has a large number of SKU available, these products are mainly necessity goods with low marginal value for hedonistic consumption. A need to acquire diverse products (e.g., organic), premium priced products (e.g., wine) for special occasions (e.g., anniversary, birthday), or products just for health related reasons (e.g., allergies, diabetes) are yet to be served via one-stop e-tailers. In this paper, we design a mathematical model that takes into account consumers’ geo-demographics and multi-product sourcing capacity for creating critical mass and profit. Our mathematical model is a variant of Capacitated Vehicle Routing Problem with Time Windows (CVRPTW), which we extend by adding intermediate locations for trucks to meet and exchange goods. We illustrate our model for the city of Istanbul using GIS maps, and discuss its various extensions as well as managerial implications.*

**Keywords** — *Dynamic consumer-led demand, e-grocery, logistics, premium goods*

## INTRODUCTION

Little is known about the development of e-grocery delivery in the context of emerging market geodemographic conditions. And yet, there has been a marked acceleration both in scope and scale in the use of e-grocery [11]. Recent studies in Turkey show that along with e-grocery, e-shopping in general doubles every year and e-retailing has increased to 200 million dollars in 2006 from 9 million dollars in 2000 [1] [6]. Equally significant, the scope of the type of products and services sold online by the major retailers transcend various markets including, grocery, white goods, and many other services. As the scale and scope of e-grocery technologies develop and change, it is easy to overlook the fact that new technologies can stretch visions, resources and capabilities to a point where stakeholders need to re-think, in situ, what further advantages the local condition have to offer. As explained in [14], firms may compete for jurisdictional control by constructing barriers to entry and forging monopolistic and oligopolistic advantage in a particular technology or geographical market. Despite the growing presence of e-grocery delivery facilities, there has been limited examination of the ways for last mile logistic actors to add value, gain influence and shape the delivery chain.

In this paper we present an overview of the corollary of changes underpinning the e-grocery delivery chain in an emerging market metropolis’ context. The specific objectives are to: (i) investigate the role of advanced logistics in enabling further value added through extra services and more efficient use of the geographical context; and (ii) develop an outline for our mathematical model which is a variant of Capacitated Vehicle Routing Problem with Time Windows (CVRPTW) extended by adding consolidation locations. The paper is therefore still embryonic, with much work to be done on measurement, and empirical methods.

## BACKGROUND

The increasing popularity of e-shopping has led to a growing number of delivery vehicles in residential areas and the realization by users that many more services and goods are now available for delivery [15]. As home delivery increases so does (a) the number of failed deliveries and (b) the cost of using multiple independent providers [5] [9]. Recently, collection and delivery points (CDPs) have emerged as a solution [1] [7] [8]. CDPs can be unattended in the form of locker points/shared reception boxes or attended in service locations such as shop in shops, petrol stations, post offices, community centers, tobacconists, bus and underground stations and schools [12] [13]. This method, while heralded for its cost saving (mileage, environmental, time, capacity utilization) and possibility of link shopping, is still not making use of the local geography and it requires a

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specific trip by customers to collect their belongings [16]. Seeking to further develop flexibility in e-grocery delivery, while adding further services, our model exploits this reality in Istanbul's new emerging landscape.

The socio-geographical distribution of consumers in Istanbul reflects patterns found in most emerging metropolises. Therefore, our model should find applications in many countries where e-retailers tend to invest. Beyond the fact that prime catchment individuals (e.g. time poor-cash rich) in Istanbul tend to live in concentrated areas, in dwellings that have the potential to give a competitive advantage to e-retailers, and e-grocers in particular. The majority of dwellings in Istanbul are formed with three different types of accommodation: 1) individual homes or apartments without any security or common/shared services, located in the old city center; tending to be older buildings in small streets with little parking opportunities, 2) small complexes of 25-30 dwellings with security, and 3) large complexes with 200+ dwellings. Type 1 represents a classic case for the CDP concept, while types 2 and 3 show potential for our model. For types 2 and 3, other opportunities include: a) most of the inhabitants being recently relocated and often lacking retail experience in the immediate neighborhood where the retailing structure is often poor; b) IT infrastructure being provided to some dwellings with instant access to e-retailers, c) drop-off and storage areas being present as part of the security services, and d) the possibility for socio-demographic and life style segmentation.

In addition, to match the requirements of modern lifestyle, our proposed framework includes the extra difficulty of delivering premium or variety goods (e.g. organic fresh vegetables, fish, and special occasion products) that are not typically available from the e-retailer's catalog and must be pulled from elsewhere in the supply network. The logistics aspect of our approach addresses exactly this: design and execution of a network system where goods are acquired from (possibly different) vendors at multiple locations in the supply network and delivered to each customer. This dimension of last-mile delivery is in fact lacking in many previous studies in the literature where standard versions and extensions of the vehicle routing problem (VRP) are studied (see [3] [4] for surveys on VRP and [2] [10] for more recent related studies). Our work extends these studies by bringing into the overall picture premium source locations, consolidation points for transferring goods between vehicles, and the possibility of multiple store sourcing for any given order, and it attempts to explore any potential value that may be realized as a result.

## MODEL

The general setting in our model is that two sets of vehicles operate, one originating at the store from which standard e-delivery products are assembled and shipped, and the other originating at a depot location, visiting premium source locations for customers who have premium products in their e-basket. We further assume that consolidation points are activated whenever premium products are ordered, and each customer is associated with a single consolidation point from which all premium products are picked up before final delivery.

The following notation is used in our model:

$I, I^p$	: set of all customers and set of customers that require premium products, $i \in I$ , $I^p \subseteq I$
$L$	: set of all consolidation points, $l \in L$
$S^o, S^d$	: set of route origin and destination locations (store + premium source depot)
$S$	: set of all route origin/destination locations, $S = S^o \cup S^d$
$T$	: set of all premium source locations
$K$	: set of all vehicles
$K^s, K^d$	: disjoint sets of vehicles originating at a store or a depot, respectively, $K^s \subseteq K$ , $K^d \subseteq K$
$c_{ij}^k$	: per km transportation cost for vehicle $k$ along arc $(i,j)$
$t_{ij}^k$	: time it takes to traverse arc $(i,j)$ for vehicle $k$
$f_k$	: fixed cost per run of using vehicle $k$
$h_l$	: fixed cost per run of using consolidation point $l$
$o_k, d_k$	: origin and destination location indices from/to which vehicle $k$ operates, $o_k \in S^o$ , $d_k \in S^d$
$J_k$	: set of locations reachable by vehicle $k$ , $J_k = I \cup L$ for $k \in K^s$ , $J_k = L \cup T$ for $k \in K^d$
$q_i, q'_i$	: capacity use of customer $i$ 's entire product list and premium-only product list
$C_k$	: capacity of vehicle $k$



$n_i$  : number of distinct premium products ordered by customer  $i \in I^p$

with the following decision variables:

$x_{ij}^k$  : 1, if vehicle  $k$  traverses arc  $(i,j)$ ,  $i,j \in I \cup L \cup S \cup T$ , 0 otherwise

$y_{il}^k$  : 1, if products of customer  $i$  to be picked up at consolidation location  $l$  by vehicle  $k$ , 0 otherwise

$z_{it}^k$  : 1, if source  $t$  to be used for servicing some or all products of customer  $i$  by vehicle  $k$ , 0 otherwise

$s_i^k$  : arrival time at location  $i \in I \cup L \cup S \cup T$  by vehicle  $k \in K$

$Q_k$  : 1 if vehicle  $k$  is used,  $k \in K$ , 0 otherwise

$R_l$  : 1 if consolidation point  $l$  is used,  $l \in L$ , 0 otherwise

The model is then formulated as follows:

$$\min \sum_{(i,j)} \sum_k c_{ij}^k x_{ij}^k + \sum_k f_k Q_k + \sum_l h_l R_l \quad (1)$$

subject to

$$\sum_{j \in J_k} x_{okj}^k \leq Q_k, \forall k \in K \quad (2)$$

$$\sum_{j \in J_k \cup \{d_k\}} x_{okj}^k = 1, \forall k \in K \quad (3)$$

$$\sum_{j \in J_k \cup \{o_k\}} x_{jd_k}^k = 1, \forall k \in K \quad (4)$$

$$\sum_i x_{ih}^k = \sum_j x_{hj}^k, \forall k \in K, \forall h \in I \cup L \cup T \quad (5)$$

$$\sum_{k \in K^s} \sum_{j \in J_k \cup \{d_k\}} x_{ij}^k = 1, \forall i \in I \quad (6)$$

$$s_i^k + t_{ij} - M(1 - x_{ij}^k) \leq s_j^k, \forall i, j \in I \cup L \cup S \cup T, \forall k \in K \quad (7)$$

$$y_{il}^k = 1 \Rightarrow s_l^k \leq s_i^k, \forall i \in I^p, \forall l \in L, \forall k \in K^s \quad (8)$$

$$\sum_{k \in K^s} \sum_l y_{il}^k = 1, \forall i \in I^p \quad (9)$$

$$\sum_{j \in J_k \cup S^d} x_{lj}^k + \sum_{r \in J_k \cup S^o} x_{rl}^k \geq y_{il}^k, \forall i \in I^p, l \in L, k \in K^s \quad (10)$$

$$\sum_{k \in K} \sum_j x_{jl}^k \leq R_l, \forall l \in L \quad (11)$$

$$\sum_{k \in K^d} \sum_{t \in T} z_{it}^k = n_i, \forall i \in I^p \quad (12)$$

$$y_{il}^k = 1 \text{ and } z_{it}^{k'} = 1 \Rightarrow s_l^{k'} \leq s_i^k, \forall i \in I^p, \forall l \in L, \forall k \in K^s, \forall k' \in K^d \quad (13)$$

$$\sum_{j \in J_k \cup \{d_k\}} x_{tj}^k \geq z_{it}^k, \forall i \in I^p, \forall t \in T, \forall k \in K^d \quad (14)$$

$$\sum_{i \in I} q_i \sum_{j \in J_k \cup \{d_k\}} x_{ij}^k \leq C_k, \forall k \in K^s \quad (15)$$

$$\sum_{i \in I^p} q'_i \sum_{t \in T} z_{it}^k \leq C_k, \forall k \in K^d \quad (16)$$

$$a_i \leq s_i^k \leq b_i, \forall i \in I, \forall k \in K^s \quad (17)$$

$$x_{ij}^k \in \{0,1\}, \forall \text{arc}(i,j), \forall k \in K \quad (18)$$

$$y_{il}^k, z_{it}^k, Q_k, R_l \in \{0,1\}, \forall i \in I, \forall l \in L, \forall t \in T, \forall k \in K \quad (19)$$

$$s_i^k \geq 0, \forall i \in I, \forall k \in K^s \quad (20)$$

In this formulation, the objective function (1) combines three cost terms: variable cost of transportation, fixed cost of each vehicle, and fixed cost of each consolidation point. Total profit to be made serving the customers in set  $I$  is a constant, therefore it is excluded from the objective function. Furthermore, constraints (2) make sure a vehicle  $k$  does not traverse an arc if the vehicle is not used, constraints (3)-(5) are vehicle flow balance constraints at each node of the network, constraints (6) ensure that a customer is always visited by one vehicle, constraints (7) properly calculates arrival times of vehicles at each location ( $M$  is a large number), constraints (8) are if-type constraints (which have not been linearized for the sake of readability) that make sure premium products for customer  $i$  are picked up at consolidation point  $l$  by vehicle  $k$  before they are delivered to customer  $i$ , constraints (9) make sure each premium-good-requiring customer is associated with a single consolidation point, constraints (10) make sure a vehicle serving customer  $i$  enters consolidation point  $l$  if the premium products ordered by customer  $i$  are to be picked there, constraints (11) make sure only used consolidation points are visited, constraints (12) ensures correct number of premium source locations are visited for each customer, constraints (13) make sure premium goods are dropped at consolidation points before they can be picked by vehicles en route to customers, constraints (14) ensure that a vehicle enters a premium source location if a customer is associated with that location, constraints (15)-(16) make sure vehicle capacities are not violated, and finally constraints (17) ensure the customer time windows are honored.

To solve this model, we have chosen to use a Tabu Search based heuristic VRP algorithm, which is available as part of the commercial ArcGIS 9.3 geographic information system platform and its Network Analyst extension. We use this algorithm in the next section where we solve two instances of the CVRPTW.

### AN ILLUSTRATIVE EXAMPLE

To illustrate the main concept we explore in this paper, we present an example for the city of Istanbul. We pose two scenarios: one where an e-delivery company delivers grocery products to several locations in Istanbul, and another where an extended fleet is utilized to collect high-premium goods from multiple source locations, which are then transferred to the store-originating vehicles with the final destination as customer locations. We show the potential profit increase, despite the increase in logistics costs.

The study area covers part of the asian side of Istanbul, where many elements of our model are present. We consider two different premium products, namely fish and flower. In Figure 1, these are marked with the fish and green leaf symbols respectively. Also in Figure 1 are the customer locations (star symbol), e-delivery store location (yellow square), extended fleet depot location (orange square), and consolidation points (plus symbol).

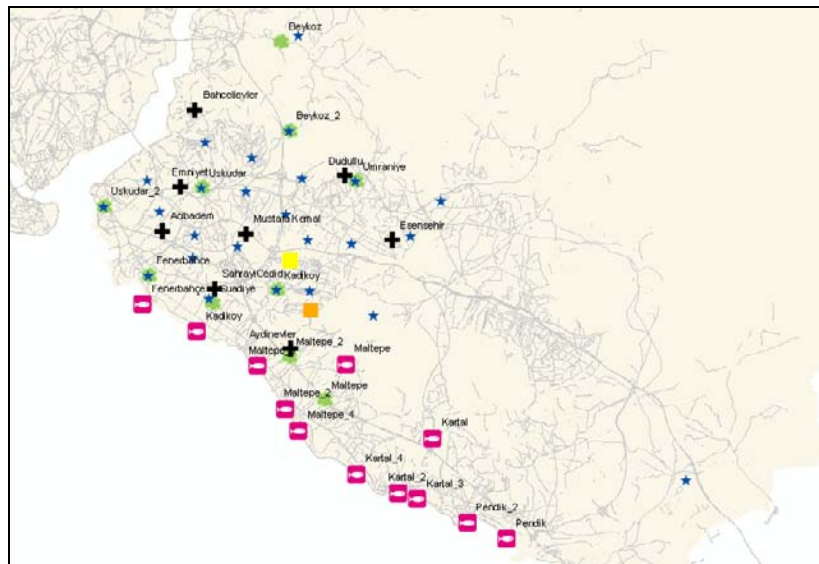


FIGURE 1  
Problem setting in Istanbul

In this first scenario, we attempt to solve the e-delivery routing problem by serving the customers in a traditional way, i.e. via a fixed number of trucks leaving the store with all products loaded and visiting customers sequentially to make deliveries. We assume a 3-hour delivery time frame allowing 9 customers per vehicle on average, with the store operating 2 vehicles. This means considering a subset of 18 customers from

the original set shown in Figure 1. We assume an average basket size of \$100, 10% of which is the bottomline profit. Note that these are customers for which only store products are available for purchase and the delivery vans drive straight to customer delivery locations after loading up at the store.

In the second scenario, when additional premium products are available for purchase, not only further customers will place new orders, but some existing customers will extend their current orders with the added choices. The additional profit generated will (hopefully) offset the increased logistics cost. In our example, a total of 25 customers request e-delivery (up by 39%), with an average basket size of \$120. Out of this \$120, 10% profit is achieved with the first \$100, and 50% profit is achieved with the remaining \$20.

We present in Figures 2a and 2b, the routing solutions obtained by a) running the traditional VRP model, and b) solving the model presented in the previous section. We assume that 3 vans operate from a single depot to visit high-premium source locations and on to consolidation points, in addition to the 2 store-originating vans. In both cases, we assume a variable transportation cost of \$1 per km. and a fixed monthly vehicle cost of \$1080 as well as a monthly \$450 for each consolidation point (which translates into \$12 and \$5 per run, respectively, assuming 3 runs a day, 30 days a month).

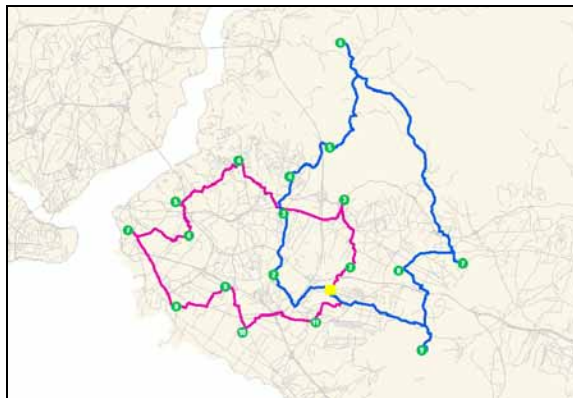


FIGURE 2A

Standard e-delivery with 2 vehicles



FIGURE 2B

"Premium e-delivery" with 3 vehicles

Our calculations, as shown in Table 1, indicate the potential profit that may be realized for the online delivery company by offering the additional premium products for e-delivery. In this example, the company incurs additional logistics cost of \$167.07 dollars, but this is sufficiently offset by the additional profit of \$320.

While our analysis shows the potential profit that may be realized from the extended service, various parameters clearly impact the amount of such profit, if any, or the breakeven point. Two of these are the basket size and the % profit margin (for standard as well as premium products). Keeping the basket size and profit margin constant for standard goods, we present a 2-dimensional sensitivity analysis of the remaining two parameters, the standard+premium basket size and the premium profit margin, in Table 2.

TABLE 1  
Comparison of standard and extended e-delivery models

	Store Products Only	Store + Premium Products
Number of customers served	18	25
Number of vehicles used	2	5
Cost of vehicle per km	\$1	\$1
Fixed cost of vehicle per run	\$12	\$12
Total km's driven	56.61	147.68
Number of consolidation points used	-	8
Cost of consolidation point per run	-	\$5
Total Cost	\$80.61 (=12×2+56.61×1)	\$247.68 (=12×5+1×147.68+5×8)
Profit from standard products	180	250
Profit from premium products	-	250
Total profit	180	500
Net profit	\$99.39	\$252.32

TABLE 2  
Net profit difference as a function of standard+premium basket size and premium profit margin

Profit Margin / Basket Size	110	120	130	140	150	175	200
10%	(72.07)	(47.07)	(22.07)	2.93	27.93	90.43	152.93
25%	(34.57)	27.93	90.43	152.93	215.43	371.68	527.93
50%	27.93	152.93	277.93	402.93	527.93	840.43	1152.93
75%	90.43	277.93	465.43	652.93	840.43	1309.18	1777.93

## CONCLUSION

Our analysis indicate that there are forgiven profit opportunities for e-grocers. As shown in our illustrative scenarios, involvement of premium goods offers possibilities in improving both the number of customers served and the basket size. E-fulfillment is clearly a complex process which needs to integrate not only logistics, retailers and consumers' logics but also reflect closely the dynamic social environment in which it is evolving. E-grocery fulfillment will need, in the future, to be seen as a tool where further added value can be derived in order to achieve sustainable growth and competitive differentiation. Identifying key logistic components, socio-demographic soft factors and understanding how these components inter-relate and react for delivering further value are prerequisites of development and implementation of a successful e-fulfillment process. This process implies that some current practices may disappear to give rise to new ones, using new logistic approaches in function of the local circumstances and users (including some reverse logistic options).

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## TRAVELERS RESPONSE TO VMS IN THE ATHENS AREA

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**Abstract** — This paper presents a case study on travelers' response to Variable Message Signs (VMS) conducted in the Athens Metropolitan area in Greece. VMS have only been installed in major highways of Athens Metropolitan Area for the last four years - just before the Athens Olympic Games 2004. The objective of this study is to examine VMS awareness, usage and the impact of information acquisition while en route, as well as to identify - quantify the role of attitudes and perception on travelers' decisions. From the data analysis it was found that 93,7% of the sample is aware of the VMS services, and one third of them have been influenced from the information provided through them. The main impact of VMS, is route switching (54,3%), followed by travel mode change (30,4%), while the majority of the respondents consider the information provided from the VMS useful, but not that reliable.

**Keywords** — Attitudes and Perceptions, Variable Message Signs

### INTRODUCTION

Variable Message Signs have been used, worldwide, to communicate traffic related messages and to provide guidance to drivers. For several years now, researchers are trying to obtain a greater understanding of the VMS impact on travelers' choices with the use of stated and revealed preference data techniques.

Up to now it appears that travelers have welcomed traffic information provision, even though they do not always comply with it. According to recent studies, the proportion of travellers diverting route due to VMSs is relatively small, (Chatterjee et al., 2002; Cummings, 1994) and it seems that the main reason for this are: (a) drivers perceived reliability and usefulness of VMSs information; (b) drivers' attention (whether they get to notice or not the messages displayed on VMSs); and (c) the way that the information is presented (figures, graphic presentation, etc.) (Chatterjee et al., 2002; Proffitt & Wade, 1998; Kronborg, 2001).

This paper presents a case study for Athens, Greece conducted in 2006-2007. It presents the results of the first survey conducted regarding the usage rate and impact of the Athens VMSs. Traveler information sources, available in the Athens area, encompass mainly conventional forms of information, such as radio and TV traffic reports, while advanced systems (such as VMSs, traffic web sites, etc.) have been only recently available in the Greek market.. In this paper, these data are used to reveal the usage rate as well as the impact of information acquisition on switching usual travel behavior.

The remainder of this paper is organized as follows. Section two presents a brief review of the "State of the Art" of VMS awareness, usage and impact on travelers' decisions. Section three presents the behavioral framework. Section four presents the data collection methodology and data analysis and section five presents the conclusions.

### STATE OF THE ART

Numerous studies have been conducted to explore drivers' behavior and switching behavior under the influence of VMS information (Emmerink et al. (1996), Polydoropoulou et al., (1996) Chatterjee et al. (2002), Can et al. (2008), etc.). In the remainder of this section, a review of the state-of-the-art on VMS usage and response to information is presented. This review does not aim to be exhaustive, but aims at presenting the key findings of research so far.

Adler et al. (1993) used a driving simulator named FASTCARS to collect data for estimation and calibration of predictive models of driver behavior under the influence of real-time information. Two alternative modeling approaches were used to model route switching behavior. One was based on a utility

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maximization approach (logit and probit estimations) for primary and secondary diversion behavior; the other was based on conflict resolution concepts to model drivers' behavior. Analysis showed that en-route diversion behaviour is influenced by familiarity of drivers with the potential alternative routes and their traffic conditions, the information provided by the VMS, the changes in travel speeds, and the drivers' risk preferences. Moreover the value of information decreases among more experienced drivers.

Emmerink et al. (1996), analyzed the impact of both radio traffic information and variable message sign information on route choice behavior. The empirical analysis was based on an extensive survey which took place in Amsterdam. The data analysis showed that gender, trip purpose and flexibility of arrival time, plays an important role regarding the degree of information influence. In a study of Benson (1996), at Washington, D.C, he found that 49% of the respondents claimed that they are influenced by VMS "often," while 38% are "occasionally" influenced by VMS.

Polydoropoulou et al. (1996) studied traveler responses under unexpected congestion and found that the propensity to take alternative routes was affected by the trip characteristics, the sources of information, and route attributes.

Wardman et al. (1997) used a Stated Preference approach to undertake a detailed assessment of VMS information effect on drivers' route choice. The data analysis revealed that the impact of VMS information depends mainly on three parameters: (a) the content of the message, (b) the local circumstances, and (c) drivers' characteristics. Additionally, the results indicate that route choice can be strongly influenced by the provision of information, on traffic conditions ahead, at appropriate points. Similarly, Peeta et al. (2000), found that the level of detail of the information that is displayed on the VMS, has a significant effect on the drivers willingness to switch.

Chatterjee et al. (2002) conducted a survey in London, to investigate driver response to different VMSs, by comparing the impacts of several message settings on route choice. Using logistic regression models, they found that the content of the message, as well as the incident location significantly influenced drivers' decision. In addition they found that only one third of all drivers noticed messages about network problems, and only few of these drivers diverted.

Peng et al. (2004), studied motorists attitudes toward arterial Variable Message Signs and their impact on switching behavior. As it appears from the data analysis two-thirds of the respondents receive traffic information through VMS more than once a week and 66% of them change their route at least once per month due to the information received from the VMSs. Additionally, drivers are more likely to divert from their route, if they believe that the diversion will save them time and will allow them to avoid traffic congestion.

Bierlaire and Thémans (2005) estimated two discrete choice models, using data from a two-year national survey in Switzerland during which both Revealed Preferences (RP) and Stated Preferences (SP) data about choice decisions in terms of route and mode were collected. It was found that people who use Internet to access the information and those who are aware of alternate routes have a propensity to switch routes.

Lee et al. (2005) examined the quality of the VMS service perceived by an individual driver, with the concept of fuzzy theory. The degree of satisfaction with VMS service was identified, taking into consideration the variance of human perception and the degree of importance of the performance criteria.

Erke et al. (2007) studied the effect of route guidance Variable Message Signs on speed and route choice. Traffic counts showed that VMS are effective in rerouting traffic and about each fifth vehicle that would have continued on the motorway changed route and followed the recommended one.

Can et al. (2008) conducted a quantitative assessment of the potential effects of Variable Message Signs (VMS) information, displaying travel times on both original and alternate routes, on drivers' en-route diversion behavior. The data analysis show, that freeway drivers' en-route diversion decision can be strongly influenced by the provision of information on travel times for both regular and alternate routes, and that the impact of information depends on driver, route, and VMS message characteristics.

Choocharukul (2008) studied the interrelationships among the likelihood of making route diversion, attitudinal variables, and several exogenous factors such as socioeconomic and travel characteristics of the motorists. Results from the structural equation model reveal that the stated route diversion can be determined from two attitudinal constructs: (a) VMS comprehension; and (b) perceived VMS usefulness, while other key variables that appear to be of statistical significance are education, gender, age, daily mileage, and trip purpose.

Research so far, has identified the main factors that influence drivers' switching behavior, as well as their willingness to acquire traffic information through VMSs. These factors can be distinguished in the following four categories: (1) drivers' socio-economic characteristics, such as age, gender, etc.; (2) information content



and VMS location; (3) trip characteristics, such as trip purpose, drivers' familiarity with the network; and (4) drivers' attitudes and perceptions, such as drivers' risk preferences, perceived usefulness of VMSs, etc.

The research presented in this paper takes into account the above-mentioned findings and develops and validates a travelers' behavioral framework towards VMSs for the Athens region.

## BEHAVIOURAL FRAMEWORK

Figure 1 presents the behavioral framework for VMS usage and response to VMS information acquisition. This general framework consists of four stages which are further analyzed.

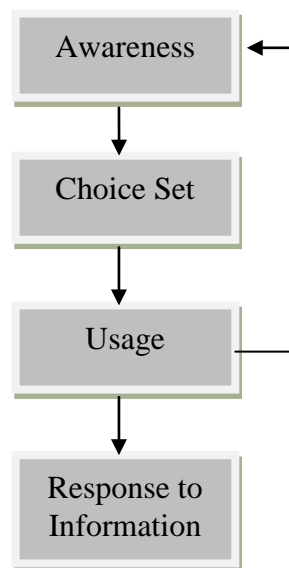


FIGURE 1  
Behavioral Framework of VMS Usage and Information Acquisition

- **Awareness:** This stage relates to travelers knowledge and perceptions regarding VMS services and their attributes.
- **Choice Set:** This stage reflects individuals' potential set of choices in order to respond to a specific travel need
- **Usage:** The third stage is usage, where travelers' decide to use the services provided through variable message signs. Previous experiences from the system usage are crucial for the future repeat usage.
- **Response to Information:** The last stage reflects travelers' response to information and indicates the changes that occur in individuals travel behavior, as well as the degree and frequency of them.

## DATA COLLECTION AND DESCRIPTIVE STATISTICS

The objective of this study was to examine VMS awareness, usage and the impact of information acquisition while en route, as well as to identify and quantify the role of attitudes and perception on travelers' decisions. For the data collection, computer aided telephone interviews (CATI) were conducted.

The research was realized in two "waves". The first wave began in September 2006 and was completed in October of the same year. In the first wave the respondents were households of Attica and specifically of the municipalities Psychico, Chalandri and Cholargos. The choice of these regions was based (a) on the high rates of application and use of new technologies; and (b) on their location, regarding the highways that allocate variable messages signs.

The second wave of data collection began in June 2007 and was completed in September 2007. The study area was expanded and the data from the second wave came from municipalities all over Attica.

The main reason that led to the realization of the second wave was that during the data analysis of the first wave, it was observed that the percent of trip changes after VMS information acquisition was significantly low, due to the lack of alternative route/mode choices. Indeed, after a thorough investigation of the geographical location of those areas, the choices of alternative routes and/or modes were limited.

A total of 175 observations were collected (75 First wave and 100 second wave). Table 1, presents selective characteristics of the sample. As it appears, the average age is 41 years old (standard deviation 14,8 years), while the majority of the sample are currently working and have a cellular phone (92,6%). Additionally, almost 60% has an internet connection, out of which 60,2% has ADSL.

TABLE 1  
Socioeconomic Characteristics

Characteristics		Percent (%)
Gender	Male	45,7
	Female	54,3
Occupation Status	Employed	62,3
	Retired	10,9
	Housewives	11,4
	Military	1,7
	Students	7,5
	Unemployed	2,3
	No Answer	4
Annual Individual Income	Less than 10.000€	21,7
	10.001 – 20.000 €	34,3
	20.001 – 30.000 €	14,9
	30.001 – 40.000 €	2,9
	Above 40.001 €	1,1
	No Answer	25,1
Internet Connection	Yes	58,9
	No	37,1
	No Answer	4,0
Mobile Phone	Yes	92,6
	No	2,9
	No Answer	4,5

Figure 2 presents the habitual mode choice for several travel purposes. As it can be seen, the majority of the respondents use mainly their car (as drivers), for all the trip purposes. The only trip purposes that car is not dominant since individuals choose to walk, is for daily groceries and short trips in town for pleasure. Additionally, as it can be seen the majority of the sample don't do sports, while they prefer to visit friends/family or travel by car for recreation purposes.

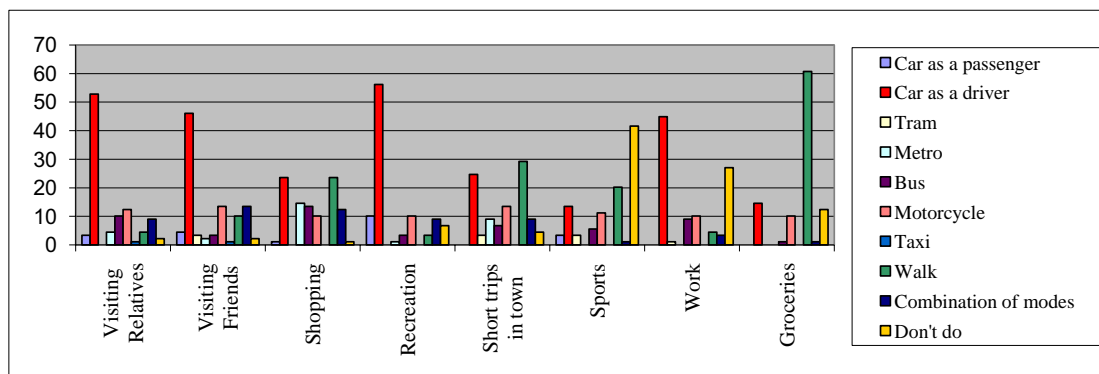




FIGURE 2  
Habitual Mode per Travel Purpose

From the data analysis it was revealed that the majority of the respondents are aware of the Variable Message Signs (93,7%) in Attica and 30% of them stated that the existence of VMS has influenced somehow, their overall travel behavior. This is consistent with the findings of MV2 (1997), where 97% of Paris drivers are aware of VMSs and 46% has occasionally diverted in response to information. The main impact of the VMS existence in Athens and not of a specific message, is route change (54,3%) followed by mode change (30,4%).

Almost 70% of the respondents have acquired sometime in the past deliberately or randomly information from other sources (radio, tv, etc.). In the following table, the sources of information and the willingness of their use is presented.

As it can be seen from the table below, the majority of the sample, has received in the past traffic information from other sources randomly, while the main source of information, either prior or en route, is radio.

TABLE 2  
Information Acquisition from Other Sources

Information Source	Percent(%)
Radio prior of the trip – deliberately	5,7
Radio prior of the trip – randomly	31,1
TV show – deliberately	4,1
TV show – randomly	18
Radio en route – deliberately	1,6
Radio en route – randomly	36,1
GPS	3,4

In the following table the characteristics of the last trip that individuals acquired traffic information from a VMS are presented. It should be noted that from the 175 individuals that completed the survey, 25% didn't have either car license or private vehicle and therefore they couldn't respond the following questions.

The last time that almost 50% of the respondents acquired information from a VMS was during the week of the survey; therefore they were in a position to respond to the questions asked. The average trip time was 35 minutes, while the majority of individuals (80%) received information from a VMS randomly, during their trip. The frequency of VMS usage is approximately twice a day.

Additionally, almost 44% of the sample, was travelling to/from work, and the VMS information content received in most of the cases was estimated travel times to a specific point of the network (55,4%). From those that received information, only 15% changed something in their trip, while from those that didn't change anything, 40,5% wanted to, but there was no feasible alternatives available. According to the literature review, the most common impact of traffic information acquisition, is route change (small route changes or the route overall). In the case of Attica in some of the highways that VMS are located, there are no alternative routes.

TABLE 3  
Trip Characteristics and VMS

Trip Characteristics		Percent (%)
Search for Information	Yes	22,9
	No	77,1
Information Acquisition	Randomly	80,2
	Deliberately	15,3
	No	4,6
Trip Purpose	Return Home	7,4
	Trip to Work	14,0
	Return from Work	29,8
	Recreation	19,8
	Visiting friends/family	8,3

Trip Characteristics		Percent (%)
	Doctor visit	4,1
	Don't remember	9,1
	Other	7,4
Information Content	Part of my route was closed	5,0
	Traffic Congestion	15,7
	Estimated Travel Time	55,4
	Other	5,0
	Don't Remember	19,0
Response to Information	No Change – There was no reason to	50,0
	No Change – There was no feasible alternative	34,0
	Small route changes	8,5
	Change Route	6,4
	Other	1,1

The respondents were also asked to recall the last time that they received information from a VMS regarding the existence of an “extreme” event (major accident, strike, etc.). From the 131 individuals, only 53 recalled such an event. The majority of the respondents (64%) were informed about an accident, while 20% was informed about the closure part or whole of their route. In these extreme events, 19% of the respondents changed completely their route, while 49% didn't change anything because of the lack of available alternatives.

The following figure, presents the reliability and usefulness of VMS, with the use of a 5-scale, where 1 is extremely useful/reliable and 5 not useful/reliable at all. The majority of the sample considers the information provided through VMS as extremely or very useful but not that reliable. It should be noted that above 50% of the respondents stated that they check the reliability of the information, especially if it concerns estimated travel times.

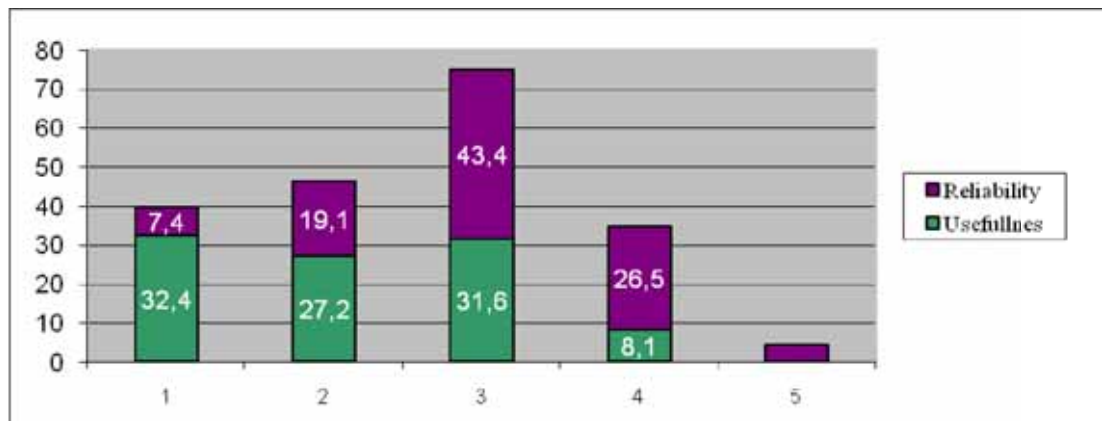


FIGURE 3  
VMS Reliability and Usefulness

In the following figure, the feelings of the respondents, after VMS information acquisition is presented. As it appears almost 44% of the respondents feel relieved, while 30% feels anxious.

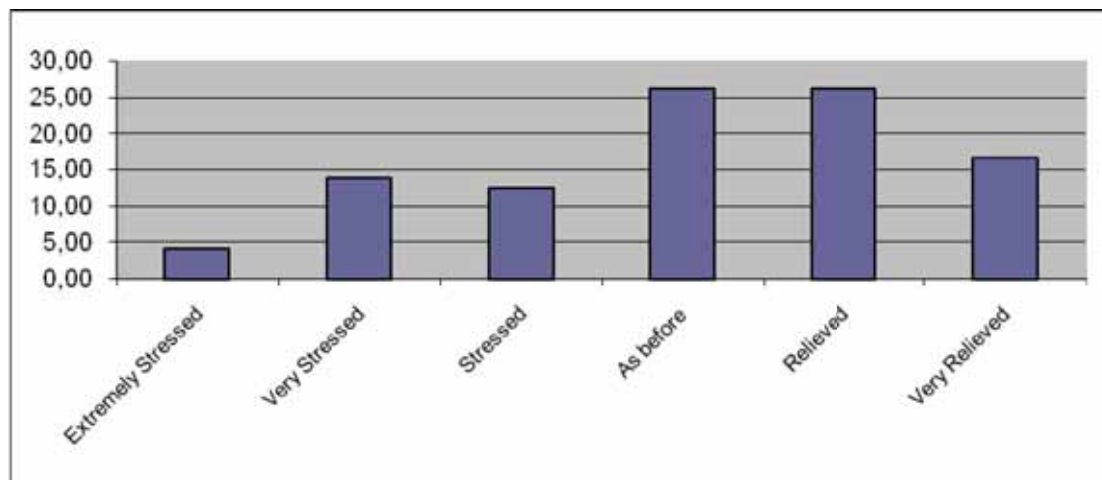


FIGURE 4  
Feelings after Information Acquisition

The following figure, presents the first choice of the respondents regarding the desired content of VMS information. As it appears, the majority of the sample desires information regarding accidents and estimated travel times. As a second choice the majority (33%) chooses information about accidents and estimated clearance time, followed by information for alternative routes (24%).

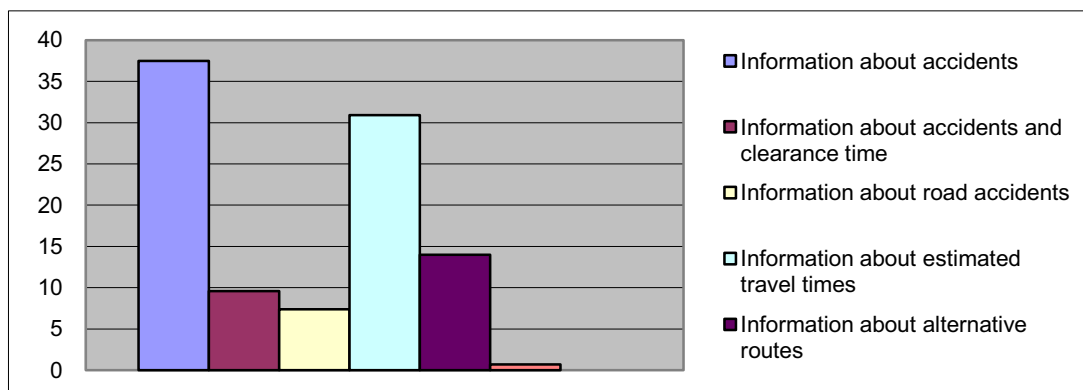


FIGURE 5  
Desired Information Content

Table 4 presents the degree of agreement or disagreement of the respondents with the following statements. A 5-scale was used, where 1 is completely disagree and 5 completely agree. As it appears, the majority of the workers face daily congestion to their work, while it is important to them to arrive at work a specific time. In addition, the majority of the respondents find waiting time in Public Transport (PT) stops/stations unpleasant and annoying and it would be easier to them to take a PT mode if they knew the exact PT mode arrival time. As far as it concern traffic information, the majority of the respondents believe that it is necessary, however only 33% of them actually search for info.

TABLE 4  
Attitudes and Perceptions

Statements	Mean / (Std. Dev.)
I always estimate travel time prior to my trip	3,87 (1,06)
I prefer to learn well a route and follow it	3,80 (1,22)
I like to be aware of all the available alternative route before I choose one	3,96 (1,19)
I don't like discovering new routes	2,52 (1,28)

Statements	Mean / (Std. Dev.)
I believe that traffic information is unnecessary	1,85 (0,94)
I believe that traffic information reduce stress	3,84 (0,97)
I don't like risks	3,15 (1,29)
When I need information concerning my route, while en route, I prefer to ask someone instead of VMS	2,99 (1,23)
It is important to arrive at work a specific time	4,69 (0,89)
I have a specific work schedule (9-17)	4,11 (1,68)
I found daily congestion on my route to work	4,24 (1,50)
Twice a week I found unexpected congestion on my route	3,91 (1,35)
The last three years I have seriously consider the possibility to change either work or home, in order to reduce the time I spend in trips	2,79 (1,79)
I am not satisfied from my daily trips	3,75 (1,05)
Now I travel in my usual route faster than I did 12 months ago	3,08 (1,52)
I find waiting time for the next bus/train annoying	4,13 (1,12)
The criminal or annoying behavior of others in PT modes concerns me	4,14 (1,01)
It would be easier for me to take a PT mode, if I knew the exact arrival time	4,10 (0,89)
PT modes are insufficient in the area I live	3,09 (1,49)
I need my car to work (carry tools, etc.)	3,88 (1,85)
Finding parking space near my house is extremely difficult	3,84 (1,43)
Finding parking place near my work is extremely difficult	3,99 (1,75)

## CONCLUSIONS

In the presented research, RP data from a CATI survey have been used to study travelers' response to VMSs in the Athens area. In the survey, individuals were asked about their familiarity with traffic information sources available in the region. Special attention was given to the information impact on drivers usual travel behavior due to VMSs.

Overall 94% of the respondents is aware of the Variable Message Signs in Attica and nearly one third of them have altered permanently their usual travel behavior because of them. Additionally, the majority of the sample has acquired traffic information either deliberately or randomly, from other sources in the past (tv, radio, etc.).

VMS usage is quite common since travelers acquire information through VMSs approximately twice a day, mostly during their trip to/from work. The average travel time during which drivers receive information, is 35 minutes and the information content, in most of the cases is estimated travel times (55,4%). The impact of VMS information acquisition is relatively small, since only 15% of the respondents changed something in their trip. However it should be noted that from those that didn't make any change, 40,5% wanted to, but there was no feasible alternatives.

The majority of the travelers surveyed believe that VMS in Athens, provide extremely or somewhat useful travel information but not that reliable. Additionally, it appears that almost 44% of the respondents feel relieved after the information acquisition.

Most of the respondents believe that traffic information is necessary, however only one third of them actually search for traffic information prior to their trip or while en route. In most of the cases respondents acquire information unintentionally from radio.

## ACKNOWLEDGEMENT

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## REGIONAL AIRPORTS AND LOCAL DEVELOPMENT: THE CHALLENGING BALANCE BETWEEN SUSTAINABILITY AND ECONOMIC GROWTH

*Rosário MACÁRIO<sup>1</sup> and Jorge SILVA<sup>2</sup>*

**Abstract** — *The airports stimulate the regional economy through the use of local regular services concerning passenger and cargo, catering and food, maintenance and equipment supply, and ground transportation; but the catalytic effect over the regional economy also affects retail shops, restaurants and hotels, the tourism industry and the generation of local taxes. However this multiplier effect, despite having the immediate effect on economic growth, requires other hard and soft investments in complementary infrastructures for the sustainable development of those regions. Otherwise, some economic growth will occur but with a rather fragile support that will not produce an effective multiplier (or catalytic) effect. This reflection and the evidence obtained in some Portuguese case studies lead to the concern that we might be facing an urgent need to change methodologies for infrastructure impact assessment and to evolve towards multi-methodologies where quantitative and qualitative methods have to come together in order to reflect the effective dynamics of the real world.*

**Keywords** — *Local Development, Non-Spatial and Spatial Impacts, Regional Airports, Sustainability*

### INTRODUCTION

There is an unanimous opinion among researchers that transport infrastructures are potentially influent in the economic performance of the regions, mainly because “(...) expanding the use of existing resources (labour, capital, etc.), attracting additional resources (...), and making (...) economies more productive”, [1:104].

But such enthusiasm should not lead us away from the realistic assessment made by Izquierdo [2] that infrastructures by themselves do not generate neither economic development in general neither regional development. They have to be considered as an element of territory.

This position is also corroborated by the EIB - European Investment Bank, when it underlies that the objective of the politics of regional development is to create the conditions for an autonomous and supported growth of the per capita income of the less favoured regions, allowing it to approach the one of European average; adding that the infrastructure “(...) contributes only indirectly to this aim: in itself, it has only a marginal multiplier effect, as infrastructure use does not contribute significantly either towards increasing the national product, the creation of permanent jobs or the transfer of technology, nor does it have an impact as a purchaser on the other regional industries or services. (...) [I]nfrastructure may, though, act as a catalyst in promoting development”, [3:9].

The debate around the relationship between regional development and, specifically, the transport infrastructures is not recent and has been one preferred theme, either among the specialists in this matter, or among the public in general, or even between politicians. For some of them, such link became so obvious that already does not deserve a special reference allowing, this way, not only to create the illusion that the transport is simply a consequence of the demand, but also to minimize the impact of any empirical evidence to this respect. In fact, it is possible to make the evidence, on the remarkable correlation between the economic and transport growth. In this context, decoupling is a long standing ambition aimed at by many authors, “(...) if it can be economised then we should expect to see a reduction in the amount of transport necessary to achieve a given level of welfare”, [4:2].

In the opinion of Vickerman [4:2] “(...) it appears that transport faces both a strong positive income elasticity of demand and an overall price elasticity not far from unit. There is a suggestion that in terms of both money and time budgets there are a given (proportional) allocation to transport”. In fact, as it became more accessible and proportionally cheaper, now it is possible to go even more far away in the same period of time and - also proportionally, within the same budget, “(...) even the telecommuter spends about the same

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time in the week travelling as the daily commuter, taking the benefits of the telecommuting freedom to live in a better area”, [4:2].

But this is not developed without risks. The framework for urban mobility differs substantially from one country to another and even between cities of the same country but, whatever the choices made, in practical terms cities are major sources of output, of productivity, of growth and of wealth, and this characteristic is very likely strengthened by the city size. Although reported as not completely proven, some authors [5:174]-[6:75] advance the hypothesis that the synergetic effect comes from the fact that the bigger the city the larger is the effective labor market.

Despite this recognized potential, Prud’homme also alerts for a common pitfall [5:176] that is, if jobs and homes are poorly located, and/or if the transportation system breaks down, then the city will be formed only by several independent small markets without appropriate scale to induce higher productivity. So, the good interaction between land-use and transport is by itself a factor that influences the potential of a city as major source of productivity (e.g. output or growth) and, consequently, its long term sustainability will result from a good city management.

Accessibility together with globalization produced also remarkable effects in the transport of goods, not only those for the supply of the raw materials but also those for the transaction of the manufactured items.

In his context - and even weighing all the arguments, it is not easy to establish the true essence of the relationship between the infrastructures of transport and the regional development, mainly because we are facing two types of impacts, which Vickerman [7] thus classifies: non-space impacts - those occurring as an imposition in the economic activity - in general, by the investment in infrastructures; space impacts – those occurring as a consequence of different performances, in different places too, by the infrastructures themselves.

The analysis is even more challenging if we consider also the time span of the production of effects where we can consider [8:236]:

Results, are the benefits (or disbenefits) that the recipients of the services delivered by the system obtain from their utilization. It is an end state dimension, an immediate outcome, centered in the system user and internal to the airport system. Results should be subject to regular monitoring and it is through the evaluation process that they provide the first information feed-back for any possible adjustment required in the implementation of an action or measure. A good illustration of a result is the improvement of accessibility with the implementation of a new regional airport or the enlargement of an existing one, e.g. an enlargement of the territorial area that can be reached within a certain time threshold, given the increase connectivity.

Impacts, are consequences that can either affect the recipients of any process, action, project measure or policy package, or any third parties. Impacts are spread along time, and can be any socio-economic change that accrues directly or indirectly from any implemented action or measure. Following the methodological guide for evaluation used by the European Commission [9:10] impacts can be of three kinds:

- direct impacts, that is specific impacts observed among direct beneficiaries of the system which can be reflected either in short term or in long term. These can be further disaggregated in the effect they produce on the relations between the beneficiaries and the systems:
  - first, only by changing perceptions, that can be seen as a direct effect over potential users and so influencing their choices; and
  - second, by introducing behavioral adjustments, as a consequence of the change in perceptions, that represents a secondary effect since they will progressively spread throughout society.
- indirect impacts, which affect indirect beneficiaries;
- global impacts, which are the ones that can be observed at macro-economic and macro-social levels.

Finally, system evolution is the structuring effect that results from all these impacts. Therefore sustainable changes act as drivers of system evolution. The feed-back cycles entail an evaluation process that enables to decide whether the system needs correction of its path and where the improvement process should be focused, and this is where spatial versus non-spatial effects and results versus impacts should be confronted.

## **EFFECTIVENESS OF TRANSPORT INFRASTRUCTURE**

### **Non-Spatial Effects: Investment and Productivity**



The approach to the relationship between the infrastructures and the development on the basis of the analysis of the effects imposed for such investments in the economic activity is, perhaps, the most generalized and the most argued during the last years, mainly since the arguments presented about this matter for Aschauer [10]-[11]. In the opinion of this author, the impact of the infrastructures - acting in this particular as public goods, reflects itself directly into the economy, raising the level of the economic activity and stimulating the productivity of the private capital; and so, it must be modelled as an additional factor in the general function of production.

However, several critics emerge on account of the role played, in this particular, by the public infrastructures, mainly because the respective initial impacts “(...) would be to crowd out private investment by raising either or both the level of taxation and the interest rate”, [4:7]. For the same author this was, precisely, the main reason of the softening of the public investment in infrastructures verified in many countries in the decades of 70 and 80 of the XX century, which consequences re-echo itself, still today, in the quality of the services given for many of them.

### **Non-Spatial Effects: Transport and Market Integration**

For an evaluation of the global impact of the transport in the market integration, we assume that a reduction of the transport costs means, not only the incentive to exportation - and, necessarily, the perspective of an increase of the income, but also the other face of the same coin, e.g. the *threat* of more competitive imports, as accessibility is indeed a two way road - imposing thus to the (local) industry a reorganization, an increase of efficiency, and a reduction of the production costs.

So the process described is absolutely similar to the one verified when reduction - or elimination, of certain barriers between economic spaces occurs. In both cases, the most optimistic forecasts collide with the reality: a reduction of the transport costs transforms each territory in a positive way but leaving it eventually more vulnerable to the exterior. To this respect Vickerman [4:9] underlines some “(...) important feedback effects in the system”: first, it is necessary to take in mind the impact of the increase of the production in the markets: in case that these evidence bottlenecks; second, the increment of the economic activity by the reduction of the transport costs can lead precisely to contrary effects of those initially desired: the inherent increase of the demand of transport can lead to the congestion of some parts of the network justifying, in turn, the increase of such costs. The effect of traffic inducement [12] comes in support of this argument.

### **Non-Spatial Effects: Transport and Endogenous Growth**

Many of the authors who mention the endogenous growth [13]-[14]-[15]-[16] admit that certain changes into this level can contribute for the growth of the economy, “(...) rather than a shock to the system which shifts the level upwards but ultimately leads to a return to an exogenously given underlying rate of growth”, [4:9]. So, the investment in infrastructures of transport will have a rebound effect into: the processes of industrial reorganization - through, either the entrance and the exit of companies, or the search of widened markets; the rhythm of transference of the innovation and the technology - following up that of the exchange of information flows; the increment of the factors which, in its set, concur for the competitiveness index.

However, a word of caution is also required here since underlying this rational is the presumption that sectors using transport as productive factors are perfectly competitive and thus almost immediately incorporate in price the variation of transport costs, which does not happen always.

### **Spatial Effects: Companies Competitiveness**

Rietveld and Bruinsma [17:360] argue that “(...) in the regional economic dynamics, transport infrastructure improvements can have different impacts in firms. First, existing firms might grow or decline; second, new firms may emerge; third, infrastructure improvements may influence the relocation decision of existing firms”.

Other authors [18]-[19]-[20] argue that transport infrastructures do not represent anymore a so important factor of localization as in the past, due to in one hand the low costs of transport and, on the other hand, the increasing participation of information flows to the detriment of physical flows. Still others [21]-[22]-[23], underline that the current industrial reorganization - based in a competitiveness where the time factor is of capital importance, made the distribution and the production systems more dependent of the transports and, therefore, of the access to such infrastructures, mainly those of high quality standard. For example, Smith and

Florida [24] show in 1994 that the Japanese companies of the automobile sector which fixed themselves in the USA elected, as main factor of localization, precisely the access to the highway.

To understand the rational at the core of this debate it is necessary to take in account the set of effects through which the transport infrastructures impose themselves the organization of the companies and in the respective space distribution and, therefore, in the standards of development of the regions where they are implemented [25]: of the location decision; of the area of market and the level of competitiveness; of the organization of the production and the structure of the supply; of the logistic.

### **Spatial Effects: Transport and Labour Market**

Holl [25:540] underlines that “(...) there are potentially important effects from transport improvements regarding the size of the regional labour market area and firm’s access to specialised labour skills (...)”; an interaction that Vickerman [4:15] verifies in two distinct levels: “(...) first, labour is a major input to all activities and is, in most cases, locationally specific in that it has to be physically present for the activity to take place. Secondly, transport affects labour both as an input to production (commuting), and as an input to other activities (social, leisure, etc.) which constitute the final demand for activities”.

In a first reaction, the area of work market increases: with the reduction of such costs, the workers can now move themselves more far, at the same (total) cost. This mechanism induces, in general, a bigger competitiveness in the local work market by the forces of other regions making - not rarely, a reduction of the wages and/or an increase of the unemployment. But also it allows the local workers the possibility to reach other markets, in other regions, “(...) which could have the effect of bidding up wages as firms seek to retain staff”, [4:15]. Besides, the negative impacts of such mechanism into the job levels and wages are ambiguous and depend on the specific characteristics of the job and of the man power in each region. In a second reaction, it is expected the appearance of migration (residence speaking) phenomena: a decreasing of the costs of the commuting movements can transform the region in appraisal more attractive for all of those who, even working outside it, look now to install themselves there. In this particular, also the unexpected increment of the supply of man power can imply, locally, some problems at the level of the wages and/or of the job; *counterbalanced* however - and eventually, by emigration movements.

### **Spatial Effects: Transport and Real Estate Market**

The impacts which a reduction of the costs of the transports, in general, and of the commuting movements, in particular, can entail, allows the evidence on the complexity of the underlying phenomena: any action in that direction origins a set of reactions; which, in turn, interact with the original actions generating new reactions; and thus successively - as in any dynamic system [26]. This justifies the answers given - and almost in simultaneous, for the work and the housing markets, as a result of the implementation of a new infrastructure, despite its dependency “(...) on the degree of slack in both of these markets which will determine whether prices change rapidly or slowly”, [4:16].

It is largely recognized that the work market cannot be dealt independently from any others mainly that of the housing - besides it appears, nowadays, each time more overlap with the increasing importance imputed to the families where more than one of its elements works externally. On the other hand, it is recognized the close relationship between the housing market and the infrastructures of transport - evidencing the direct advantages which this market gathers from there, perhaps even more than from that one of work. In this context, it is not difficult to understand the correlation between both markets, neither the advantages / disadvantages that balance / unbalance situations that can be produced between both.

### **EVIDENCES FROM PORTUGUESE CASES**

The theoretical synthesis of the previous chapters suggests the decisions on regional airport should consider all the diversity of effects referred and, even more, suggest that some backcasting methods should be used to ensure the effects produced in short and long term correspond to the attainment of objectives defined at the outset of the investment decision. The need to evolve in this direction with impact assessment methodologies accrues from the evidence obtain observing regional airport cases in Portugal.

It is easy to understand the positive impact of the airport infrastructures on a certain region, either for the jobs that may create directly, or for the development of complementary activities acting themselves as catalysts of

the economic growth. These are the so called multiplying effects. The airport infrastructures located in inner regions carry out an important role as connectivity *interfaces* with the most developed metropolitan areas.

This means, in the Portuguese context, an approach between the Interior and the Coast, contributing significantly for the reduction of the regional asymmetries. The opening of some university hospital centres, as well as several high level teaching and research institutions, underline the need of an easy and fast mode of displacement of material and human resources of high added value to/from regions of the Interior - a challenge which the airport infrastructure as the capacity to effectively answer.

In Portugal the principal airport network located in the continental territory is composed of the Airports of Oporto, Lisbon and Faro. The remaining aerial civil infrastructures compose what is designated by secondary network of aerodromes, equipped to serve operations of general aviation. These infrastructures have survived over the years, out of the willingness of local governments and quite only for local enjoyment instead of effective network nodes [27].

## **PROPOSAL FOR EVALUATION OF CURRENT METHODS FOR INFRASTRUCTURE IMPACT ASSESSMENT**

Due to legal obligation all the investments referred have been preceded by cost benefit analysis presumably done with due rigour. It seems thus to be evident that we need to evolve in the impact assessment methodologies in such a way that these method can be an effective tool for policy monitoring.

The result of the synergetic effects caused by the implementation of an airport infrastructure in territory in all dimensions is a structuring effect. Therefore sustainable changes tend to act as drivers of evolution and feed-back cycles should be envisaged entailing an evaluation process that enables to decide whether the intervention needs correction of its path and where the improvement process should be focused.

By definition feed-back cycles assess strategic objectives against impacts and operational objectives against results [8:253], making this evaluation complementary to the one, previously referred of cost benefit analysis. This evaluation should be based on the following set of six criteria that can be understood as quality perspectives for the effectiveness and efficiency of the investment: Relevance - appropriateness of the operational objectives of the infrastructure investment taking into account the context and the needs, problems and aspirations; Effectiveness - capacity to achieve the expected outputs, results and impacts; Efficiency - capacity to be effective at a reasonable cost; Applicability - adequacy of means to the achievement of objectives; Internal coherence - correspondence between the different objectives within the different levels of the national airport system. This implies the existence of an hierarchy of objectives within the system, with those at the lowest levels contributing to the accomplishment of the ones at a higher level; External coherence - correspondence between the objectives of the airport infrastructure investment and the ones of the national mobility and transport system.

For each of this criterion a set of indicators must be developed to allow operational monitoring and the feed-back cycle. The learning process that will result from this method will in turn, hopefully, create sufficient data and knowledge to facilitate future backcasting of the desire effects.

## **CONCLUSIONS AND RECOMMENDATIONS**

This paper represents only a first approach to a possible evolution in the impact assessment methodologies. We have made a first scan of the effects that should be considered and of their wide scope largely beyond the direct economic cost and benefit accruing from the investments. We have also provided the evidence that despite the attraction of investments in airports in the short term there is a need to balance this with the long term effectiveness and sustainability. These, in turn, can only exist if objectives are clearly drafted at the outset and monitoring is implemented to allow fine tuning of political decisions.

Still much work is to be done on deepening methodologies, devising correct indicators, designing adequate decision and monitoring processes. We believe this paper provides one more step in that direction.

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# **Chapter 8**

Transport Planning and Economics



# HOW FINANCIAL CONSTRAINTS AND NON-OPTIMAL PRICING AFFECT THE DESIGN OF PUBLIC TRANSPORT SERVICES

*Sergio R. Jara-Díaz and Antonio Gschwender<sup>1</sup>*

**Abstract** — We show that an active constraint on operators' expenses is equivalent to diminish the value of users' time in the optimal design of the fleet of a public transport firm. We conclude that a self-financial constraint, if active, always provokes a smaller than optimal frequency and, under some circumstances, larger than optimal buses.

**Keywords** — financial constraint, frequency, optimal pricing, public transport, vehicle size.

## INTRODUCTION

Recent experience with the design of bus services in Santiago, Chile, seems to confirm that Jansson's [3] assertion regarding observed planned bus frequency and size being too low and too large respectively is still a problem. We offer an explanation based upon the relation between cost coverage, pricing and optimal design variables. First we show that average social cost decreases with patronage, which generates an optimal monetary fare that falls below the average operators' cost. Then we examine why optimal frequency and bus size – those that minimize total social costs – are larger and smaller respectively than those that minimize operators' costs only for a given demand. Then we show that an active constraint on operators' expenses is equivalent to diminish the value of users' time in the optimal design problem. Inserting this property back in the optimal pricing scheme, we conclude that a self-financial constraint, if active, always provokes an inferior solution, a smaller frequency and, under some circumstances, larger than optimal buses.

## THE PRICING-RELEVANT COST ANALYSIS

The microeconomic analysis of public transport has to consider the resources provided by the operators and by the users, namely their time. Operators exhibit decreasing or constant average costs [1]-[2]-[9]. Regarding passengers' inputs, waiting time decreases with demand  $Y$  if frequency is optimally adapted. In addition, if the routes design can be modified, demand expansions induce a densification of the system, reducing access time as well. Although in-vehicle time grows with demand, because the effect of boarding and alighting on cycle and travel times, the net effect is a decreasing average users' cost, such that **the sum of the operators' and users' costs yields a decreasing total average cost**,  $AC_T$  [1]-[2]. This implies that  $AC_T$  is larger than the total

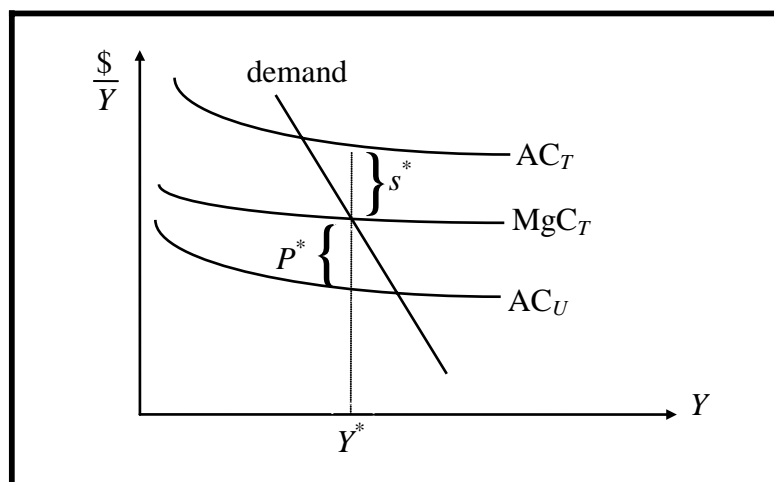


FIGURE 1  
Optimal fare and subsidy in public transport [8].

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marginal cost  $MgC_T$ , which is what users should be charged. Just as in the cars' optimal congestion pricing charge, the optimal public transport fare  $P^*$  should be obtained by subtracting from  $MgC_T$  what the users already perceive, i.e. the money value of their time given by the average users' cost  $AC_U$ . This  $P^* = MgC_T - AC_U$  happens to be smaller than the average operators' cost  $AC_O$ , which induces an optimal subsidy  $s^*$  to cover operators' expenses, as shown in Figure 1, noting that  $AC_O = AC_T - AC_U$ . For synthesis,

$$P^* = MgC_T - AC_U \rightarrow P^* - AC_O = MgC_T - AC_T < 0 \therefore s^* = AC_T - MgC_T. \quad (1)$$

## OPTIMAL FREQUENCY AND BUS SIZE BEHIND THE COST ANALYSIS

Following Jansson [3]-[4], let us consider an isolated corridor served by one circular bus line of  $L$  kilometers long, operating at a frequency  $f$  with a fleet of  $B$  vehicles. This line is used by a total of  $Y$  passengers/hour homogeneously distributed along the corridor, where each travels a distance  $l$ , i.e. a route with no singularities, equivalent to look at a portion of that route as done by Mohring [10]. If  $T$  denotes time in motion of a vehicle within a cycle and  $t$  is average boarding and alighting time per passenger, then cycle time  $t_c$  is

$$t_c = T + t \cdot (Y / f), \quad (2)$$

On the other hand, frequency is given by the ratio between fleet size and cycle time ( $B/t_c$ ), which combined with equation (2) yields

$$B = fT + tY. \quad (3)$$

The operator cost per bus-hour ( $c$ ) can be written as a linear function of the vehicle size ( $K$ ), which is general enough. Then, if  $c_0$  and  $c_1$  are constants,

$$c = c_0 + c_1K \quad (4)$$

If  $P_w$  and  $P_v$  are the values of waiting and in-vehicle time respectively, then the total value of the resources consumed (VRC) per hour is

$$VRC = B(c_0 + c_1K) + P_w \cdot (Y / 2f) + P_v t_c Y \cdot (l / L). \quad (5)$$

The first term of the right hand side are the operator expenses; the second and third are users' waiting and in-vehicle time value respectively. Access time is not included in VRC because route design is not a variable and access cost is constant. Waiting time is in general a fraction of the headway that depends on buses and passengers arrival patterns; we assume regular rates of both. Using equations (2) and (3), we can write expression (5) as a function of  $f$  and  $K$ , i.e.

$$VRC = (fT + tY)(c_0 + c_1K) + P_w \cdot (Y / 2f) + P_v (T + t \cdot (Y / f)) Y \cdot (l / L). \quad (6)$$

This expression shows that increasing frequency diminishes users' costs by reducing waiting and in-vehicle times, but increases operators' costs. As VRC increases with  $K$ , vehicle capacity should be just enough to carry the passengers on each vehicle  $k(f)$ , given by

$$k(f) = \frac{Y}{f} \cdot \frac{l}{L}. \quad (7)$$

Minimizing VRC in equation (6) subject to  $k(f) \leq K$ , which will be active always, yields

$$f^* = \sqrt{\frac{Y}{Tc_0} \left( \frac{1}{2} P_w + tY \frac{l}{L} (P_v + c_1) \right)}, \quad (8)$$

$$K^* = \frac{l}{L} \sqrt{Tc_0 Y \left( \frac{1}{2} P_w + tY \frac{l}{L} (P_v + c_1) \right)^{-1}}. \quad (9)$$



Replacing (8) and (9) into equation (6), the minimum of  $VRC$  is obtained, i.e. the cost function  $C$ , from which the total average cost  $AC_T = (C/Y)$  in equation (10) is obtained. As anticipated in Figure 1,  $AC_T$  decreases with the number of passengers ( $Y$ ).

$$AC_T = tc_0 + 2\sqrt{c_0 T \left( \frac{P_w}{2Y} + t \frac{l}{L} (P_v + c_1) \right)} + T \frac{l}{L} (P_v + c_1) . \quad (10)$$

If users' cost were not considered the design would be commanded by a minimum cost service to carry  $Y$ , finding the minimum of  $(fT + tY)(c_0 + c_1 K)$  subject to  $k(f) \leq K$ , which yields

$$f^{op} = Y \sqrt{\frac{tc_1 l}{Tc_0 L}} \quad \text{and} \quad K^{op} = \sqrt{\frac{Tc_0 l}{tc_1 L}} \quad (11)$$

$f^{op}$  is proportional to  $Y$  and  $K^{op}$  does not depend on  $Y$ ; operators would adapt to demand purely through frequency. Simulation of equations (8), (9) and (11) using simplified Santiago type parameters (Appendix 1) yields the curves presented in Figure 2. The intuitive interpretation is that any given passenger volume can be served with different combinations of frequency and vehicle size, but users' costs would be lower for high frequency-small vehicles combinations while operators' costs are favored by low frequency-large vehicles combinations, up to a limit. Other models that represent users' perception in a more complete way reinforce the separation between the two curves for both  $f$  and  $K$  [6].

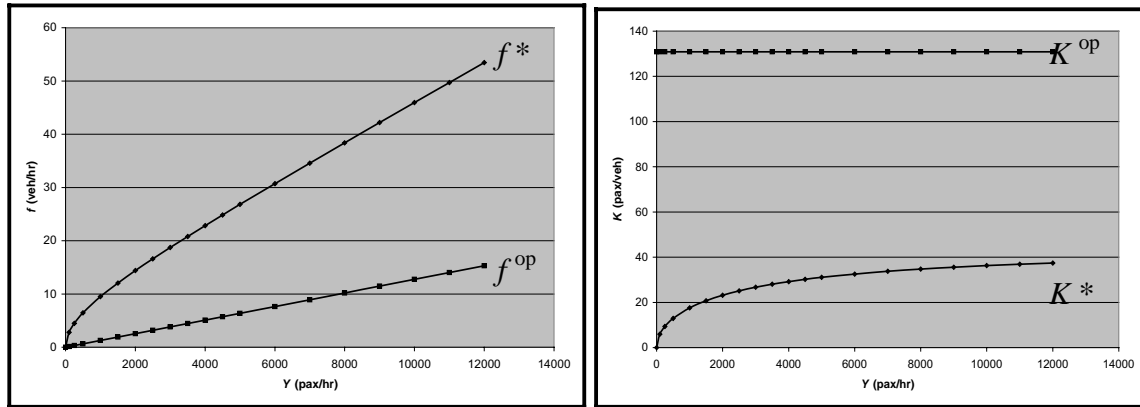


FIGURE 2

Optimal frequency and vehicle size ( $f^*$ ,  $K^*$ ) against those considering only operators' cost ( $f^{op}$ ,  $K^{op}$ )

So what is the link between the design variables – as frequency and vehicle size – and the cost analysis behind optimal pricing? As stated earlier, even under constant returns to scale for the operators total costs exhibit scale economies because the average users' cost decreases with the number of passengers, which induces a subsidy under optimal pricing. Suppressing that subsidy and imposing the entire burden on the users would make the money price equal to  $AC_O$ , in which case the minimum fare that would cover operator's cost would happen with  $f^{op}$  and  $K^{op}$  in equations (11). On the other hand, if  $P_v = P_w = 0$ , then equations (8) and (9) become (11), i.e.  $f^*$  and  $K^*$  collapse to  $f^{op}$  and  $K^{op}$ . Intuitively, then, if the actual money price (whoever pays it) varied between the minimum  $AC_O$  - that makes the service feasible for a demand  $Y$  - and  $P^* + s^*$  as defined in section 2 for this demand level, we would expect  $f$  and  $K$  to move within the area between both curves in Figures 2. Let us explore this more rigorously.

### OPTIMAL DESIGN AND COST ANALYSIS UNDER A FINANCIAL CONSTRAINT

Let us impose a self-financial constraint on the operator. The new problem is to minimize  $VRC$  in equation (6) subject to  $k(f) \leq K$  and  $(fT + tY)(c_0 + c_1 K) - A \leq 0$  where  $A = (P + s)Y$  is the sum of fare revenues and

a subsidy, not necessarily optimal. As explained earlier, the vehicle capacity constraint will always be active. Therefore  $K=k$  given by (7), and the problem can be rewritten as

$$\begin{aligned} \text{Min}_f VRC &= (fT + tY) \left( c_0 + c_1 \frac{Y}{f} \cdot \frac{l}{L} \right) + P_w \frac{1}{2f} Y + P_v \left( T + t \frac{Y}{f} \right) \frac{l}{L} Y \\ \text{subject to } & (fT + tY) \left( c_0 + c_1 \frac{Y}{f} \cdot \frac{l}{L} \right) - A \leq 0 \end{aligned} \quad (12)$$

If  $\mu$  is the multiplier of the financial constraint the resulting frequency  $\tilde{f}$  and bus size  $\tilde{K}$  are

$$\tilde{f} = \sqrt{\frac{Y}{Tc_0} \left( \frac{1}{2} \frac{P_w}{(1+\mu)} + tY \frac{l}{L} \left[ \frac{P_v}{(1+\mu)} + c_1 \right] \right)} \quad (13)$$

$$\tilde{K} = \frac{l}{L} \sqrt{Tc_0 Y / \left[ \frac{1}{2} \frac{P_w}{(1+\mu)} + tY \frac{l}{L} \left( \frac{P_v}{(1+\mu)} + c_1 \right) \right]} \quad (14)$$

After noting that these solutions replicate the optimal ones with users' values of time divided by  $(1+\mu)$ , we use **Property 1**: the multiplier  $\mu$  increases as  $A$  diminishes (see Appendix 2). So the tighter the budget, the larger is  $\mu$ , diminishing the role of time values on both frequency and bus size. For  $\mu=0$  (which occurs for  $P+s \geq AC_O$ ) equations (8) and (9) are recovered. For  $\mu \rightarrow \infty$  (which occurs when  $A$  is set exactly at the minimum operators' cost for each  $Y$  level), equations (11) are recovered. Therefore, diminishing  $A$  moves frequencies and bus sizes from their optimal values  $f^*$  and  $K^*$  to  $f^{op}$  and  $K^{op}$  in Figure 2 for all levels of demand.

Equations (13) and (14) help explaining the missing link between design and financial policies. If active, the financial constraint acts on the optimal design diminishing frequency and increasing bus size for all levels of demand, through the implicit reduction of the importance of users' time in the design problem, a hidden property that has now been unveiled. Let us investigate now how the cost curves associated with  $\tilde{f}$  and  $\tilde{K}$  look like, going back to the cost curves depicted in Figure 1, where only the case of  $\mu=0$  is represented. When  $\mu>0$  (i.e. the budget constraint is active in problem 12), by definition of the problem the total cost is no longer the minimum; it increases for all levels of demand, which raises the  $AC_T$  curve to  $AC_T'$ . On the other hand, as it is the operator cost the one that is constrained,  $AC_O$  diminishes for all demand levels. As  $AC_U$  is the difference between  $AC_T$  and  $AC_O$ , the new average users' cost curve,  $AC_U'$ , raises above the old one by an amount that is larger than  $AC_T' - AC_T$  as shown in Figure 3, which we will use to do the new pricing analysis.

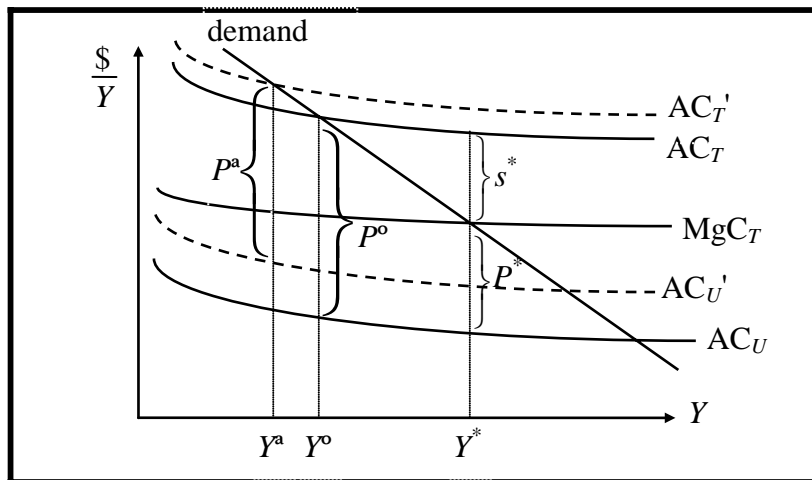


FIGURE 3

Pricing and cost analysis under a budget constraint.

Let us begin at the socially optimum point where demand equals  $MgC_T$ , with users paying  $P^* = MgC_T - AC_U$ , which requires a subsidy  $s^*$  to cover operators' costs. Let us now assume that the government does not want to subsidize the service. In this case, the users will have to cover total cost by paying a larger amount  $P^o = AC_T - AC_U$ , which will happen at a demand level  $Y^o < Y^*$ . According to equations (8) and (9), also represented in Figure 2, at  $Y^o$  both frequency and vehicle size will be lower than at  $Y^*$ . If  $P^o$  is considered unacceptably large by the users or politically inconvenient by the government, then an exogenous lower price  $P^a < P^o$  can be imposed. In this case, however, operators' costs could be covered only by redesigning the service making the budget constraint active in problem (12); as deduced above,  $AC_T$  rises to  $AC_T'$  and  $AC_U$  rises to  $AC_U'$ , up to a point where  $P^a = AC_T' - AC_U'$ . This will happen at a demand level  $Y^a < Y^o$  such that frequency is even lower than at  $Y^o$  because of two effects: because demand diminishes along  $AC_T$  (equation 8) and because total average cost increases at  $Y^a$  reaching  $AC_T'$  by diminishing frequency according to the effect of  $\mu$  in equation (13). Note that, following the same path,  $K$  diminishes by equation (9) but then increases by equation (14); the former effect is smaller the more inelastic the demand and the latter effect is larger the smaller  $P^a$ . The relation between price and the design variables becomes even more important when one realizes that setting a price below  $P^o$  induces a fall in demand because of the rise in  $AC_U$  due to the new – constrained – combination of frequency and vehicle size.

## CONCLUSIONS

Imposing a financial constraint on the operation of scheduled public transport systems acts as if the values of waiting and in-vehicle time savings were less than the ones intended, something that is not at all evident for a general policy maker (and even for modelers). Making the users bear the whole cost of public transport provision unambiguously diminishes frequency regarding its optimal social level and affects vehicle size in such a way that it can increase depending on the price level and on demand elasticity. This is a relevant result for the structural design of public transport policies, as it links operational variables as frequency and vehicle size with financial policies usually decided outside the transport field. This helps explaining the effect that overall economic policies may have on the operation of such an important public service, as seems to have been the case in Santiago, Chile, where the need of a subsidy was dismissed carelessly and a limit to the fare was exogenously imposed at the beginning of the *Transantiago* plan, causing a fleet reduction by some 30% with larger buses, a process that is now being partially reversed. It would be interesting to analyze in the future the impact of non optimal subsidies or its absence on the shape of the bus network, something that could be studied using the framework developed by Jara-Díaz and Gschwender [7] to compare the relative advantages of direct services versus those with many transfers.

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### APPENDIX 1. VALUES OF THE PARAMETERS USED IN FIGURES 2 AND 3.

Parameter	$c_0$ (US\$/hr)	$c_1$ (US\$/hr)	$t$ (sec)	$l$ (km)	$L$ (km)	$T$ (hr)	$P_w$ (US\$/hr)	$P_v$ (US\$/hr)
Value	10.65	0.203	5	10	60	2.72	4.44	1.48

### APPENDIX 2. PROOF OF PROPERTY 1.

Let us consider the convex optimization problem  $\min_x f(x)/g(x) - A \leq 0$ . This is equivalent to  $\min_x \max_{\lambda \geq 0} [f(x) + \lambda(g(x) - A)]$  or  $\max_{\lambda \geq 0} \min_x [f(x) + \lambda g(x) - \lambda A]$ , where  $\lambda$  is the multiplier of the constraint. As  $\lambda A$  does not depend on  $x$ , the internal minimization yields an optimum  $x^*(\lambda)$  such that

$$f(x^*(\lambda)) + \lambda g(x^*(\lambda)) \equiv p(\lambda) \quad (A1)$$

Then  $\max_{\lambda \geq 0} \min_x [f(x) + \lambda g(x) - \lambda A]$  can be re-written as  $\max_{\lambda \geq 0} [p(\lambda) - \lambda A]$ . Let  $\lambda_i$  be the optimal value of  $\lambda$  for constraint level  $A_i$  in problem (A5). Then

$$p(\lambda_1) - \lambda_1 A_1 \geq p(\lambda_2) - \lambda_2 A_1 = p(\lambda_2) - \lambda_2 A_2 + \lambda_2 A_2 - \lambda_2 A_1 \geq p(\lambda_1) - \lambda_1 A_2 + \lambda_2 A_2 - \lambda_2 A_1 \quad (A2)$$

Taking the first and last terms in (A2), we obtain

$$0 \geq (\lambda_1 - \lambda_2)(A_1 - A_2) \quad (A3)$$

such that  $\lambda$  increases if  $A$  decreases, which proves Property 1.

# REVENUE MANAGEMENT FOR RETURNED PRODUCTS IN REVERSE LOGISTICS

Mesut KUMRU<sup>1</sup>

**Abstract** ---Returned products take a considerable part in logistics. Recovering the returned products is one of the management issues of manufacturing companies. As an element of reverse logistics, product recovery encompasses several options, i.e., remanufacturing, repair, refurbishing, cannibalization and recycling, which are classified based on the degree of disassembly and the quality level of the recovered product. Difference in quality levels of recovered products draw different prices in the secondary markets. This situation gives rise to revenue management, i.e., to set the prices of recovered products of different quality levels such that the total revenue is maximized. One of the decision problems is the location of collection and inspection points in order to minimize the cost of reverse distribution. In our framework, we include preliminary inspection, that requires physical checking etc. and needs no substantial investment, at the collection points, and detailed inspection at the remanufacturing facility. In this paper, we modify the pricing model of Subrata Mitra to maximize the expected revenue from the recovered products. Numerical example is included for illustration.

**Keywords** --- Reverse logistics, product recovery, revenue management, pricing model, supply chain

## INTRODUCTION

Reverse logistics stands for all operations related to the reuse of products and materials. It is the process of moving goods from their typical final destination to the purpose of capturing value, or proper disposal. Normally, logistics deal with events that bring the product towards the customer. In the case of reverse, the resource goes at least one step back in the supply chain. For instance, goods move from the customer to the distributor or to the manufacturer [1]. Reverse logistics is more than just returns management. It is all activities related to returns avoidance, gatekeeping, disposal and all other after-market supply chain issues [2]. Returns management, however, increasingly being recognized as affecting competitive positioning, provides an important link between marketing and logistics. A typical framework for reverse logistics involves three main operation steps: Collecting the returned products from users, inspecting the collected products, and finally recovering or disposing the products. Reverse logistics management addresses a number of processes that have a direct or indirect impact to cost of quality. The development and implementation of a diagnostic tool to fully identify and measure this impact can indicate the way improvement of reverse logistics management may lead to final cost reduction through reduction of cost of quality. Fassoula [3] developed such a tool which is process oriented and provides cost functions for selected processes.

Product recovery is an element of reverse logistics, which is a broader term and encompasses collection, transportation, inspection and sorting, inventory management, and production planning and scheduling of returned products. There are various product recovery options, i.e., remanufacturing, refurbishing, repair, cannibalization, and recycling, which are classified based on the degree of disassembly and the quality level of the recovered product.

*Remanufacturing* is the process of restoring the quality level of a used product to that of a new product. It is the process of disassembly and recovery at the module level and, eventually, at the component level. It requires the repair or replacement of worn out or obsolete components and modules. Parts subject to degradation affecting the performance or the expected life of the whole are replaced. Remanufacturing differs from other recovery processes in its completeness. A remanufactured machine should match the same customer expectation as new machines.

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Remanufacturing is a high-grade product recovery option where the product is disassembled top art

level, all modules and parts are inspected and repaired or replaced if necessary and the product is upgraded to an as new quality level [4].

Remanufacturing provides the customer with an opportunity to acquire a product that meets the original product standards at a lower price than a new product. The flow of materials and products in this environment occurs both from the customer to the remanufacturer (reverse flow), and from the remanufacturer to the customer (forward flow). Since most of the products and materials may be conserved, essentially this forms a closed-loop logistics system. Jayaraman et al. [5] presented a 0-1 mixed integer programming model that simultaneously solves for the location of remanufacturing/distribution facilities, the transshipment, production, and stocking of the optimal quantities of remanufactured products.

*Refurbishment (restoration)* is the process of major maintenance or minor repair of an item, either aesthetically or mechanically [6].

*Repair* is the process of replacing the damaged or corrupt parts of the product. It is to restore the product to a sound or good state after decay, injury, dilapidation, or partial destruction. A repair is something that we do to mend a machine, building, piece of clothing, or other thing that has been damaged or is not working properly.

Another product recovery option is *cannibalization*, where a limited set of reusable parts are recovered and used as spare parts or for the production of new products. Cannibalization is the process (act) of removing parts from (an object, machine, etc.) to be used in another one.

*Recycling* means reprocessing of waste to recover reusable material. It is the act of processing used or abandoned materials for use in creating new products.

Remanufacturing is the most valuable product recovery option since here the value added to the product can be obtained. Remanufacturing and refurbishing options bring more value to the manufacturer than the other options. Recently, remanufacturing has been receiving growing attention for various reasons. First, government legislations require manufacturers to assume responsibility of their products after use either for disposal or for reuse, and encourage them to incorporate as many recyclable materials as possible in their products to reduce waste. Second, customers have become more environment-conscious. This creates a pressure for the corporations to adopt “green” manufacturing practices, including the reuse of discarded products, for enhanced corporate image and competitive advantage. Finally, remanufacturing is also gainful from the economic point of view. The cost of remanufacturing is typically 40–60% of the cost of manufacturing a new product with only 20% of the effort [1]. This is more attractive in the sense that the remanufactured product is of the same quality as a new product, and sold with the same warranty [7]. Also, since the same product is sold more than once, there is considerably less pressure for pricing the product when it is sold for the first time [8]. Remanufacturing is practiced in many industries, including photocopiers, computers, telecommunication equipment, automotive parts, office furniture and tires. Annual sales of remanufactured products are in excess of \$53 billion, and more than 73,000 U.S. firms are engaged in some form of remanufacturing [2]. AT&T and Xerox have saved \$100 million in 19 months and \$20 million per year, respectively, by remanufacturing used products [9][2]. In practice, all remanufactured products might not be sold because of skepticism about their quality and unsold units need to be disposed of. Also, there might be more than one quality level of the remanufactured products, which could draw different prices in the secondary markets. This situation gives rise to revenue management, i.e., to set the prices of remanufactured products of different quality levels such that the total revenue is maximized [13].

## REVENUE MANAGEMENT

Returned products are collected at various collection points, and after preliminary inspection, if found recyclable, are transported back to the manufacturer or a third-party remanufacturing facility. Otherwise, they are disposed of. At the remanufacturing facility, the returned products are subjected to detailed inspection, based on which it is decided whether they could be remanufactured or have to be disposed of. The products that go through the remanufacturing process have to be sold in the secondary markets, and the cycle is repeated. Remanufactured products, which could not be sold, have to be disposed of. Ideally, the reverse logistics activities have to be integrated with the normal manufacturing activities of a firm, but this adds to the complexity of the system since there is a high

level of uncertainty in terms of the timing, quantity, and quality of the returned products. One of the decision problems is the location of collection and inspection points in order to minimize the cost of reverse distribution. Should inspection be carried out at the collection points or at the remanufacturing facility? If inspection is carried out at the collection points, it will reduce the unnecessary transportation of otherwise useless products. But at the same time a substantial investment may have to be made for installation of sophisticated inspection equipment at all the collection points. For inspection at the remanufacturing facility only, there will be economies of scale in terms of investment in inspection equipment. Surely, there is a trade-off in between these two inspection alternatives, and this should be determined prior to revenue management stage.

The Revenue Management model considers the problem faced by a seller who owns a fixed and perishable set of resources that are sold to a price sensitive population of buyers. In this framework where capacity is fixed, the seller is mainly interested in finding an optimal pricing strategy that maximizes the revenue collected over the selling horizon. Motivation for this work is the pricing policies that are today, more than ever before, a fundamental component of the daily operations of manufacturing and service companies. The reason is probably because price is one of the most effective variables that managers can manipulate to encourage or discourage demand in the short run. Price is not only important from a financial point of view but also from an operational standpoint. It is a tool that helps to regulate inventory and production pressures

Revenue management for returned products has not been addressed in literature so far. Jayaraman et al. [10] gave an integer programming formulation of the reverse distribution problem and a heuristic methodology that was very promising in terms of solution quality. Fleischmann et al. [11] first considered the integration of forward and reverse distribution, and gave a generic integer programming formulation. They took two cases of photocopier remanufacturing and paper recycling, and showed that there is potential for cost savings if one undertakes an integrated view rather than a sequential design of the forward and reverse distribution networks. In both the papers, the decision variables were the flows and the locations of the collection centres and remanufacturing facilities. In [11], the locations of plants and warehouses were the additional decision variables.

The profitability of reuse activities is affected by uncertainty regarding the quality of returned products. The quality of returns becomes known only after the transportation of the products to the recovery site. Zikopoulos and Tagaras [12] examined a reverse supply chain consisting of two collection sites and a refurbishing site, which faces stochastic demand for refurbished products in a single-period setting, and proved that the expected profit function has a unique optimal solution (procurement and production quantities) and derived the conditions under which it is optimal to use only one of the collection sites.

Apart from other researchers who approached to revenue management problem from cost minimization point of view, Mitra [13] developed a distinctive pricing model to set the prices of remanufactured products of different quality levels such that the total revenue is maximized.

In this paper, we do a minor modification on the pricing model developed by Mitra [13] to maximize the expected revenue from the recovered products. Instead of disposal cost, we added revenues from selling scraps in the model where the preliminary inspection is included at the collection points that requires physical checking etc. and needs no substantial investment, and detailed inspection at the remanufacturing facility. Numerical example is given for illustration.

## PROBLEM DEFINITION

Regarding the product recovery options of remanufacturing and refurbishing Mitra [13] defined the problem in the following way. There is an inventory of manufactured products and remanufactured products of two quality levels. Consider remanufactured products which are “as good as new” and refurbished products which are of lower quality. The number of units in inventory for each class of products is obtained from an appropriate inventory control model. The number of units of refurbished products exceeds the number of units of remanufactured products since generally the returned products are of low to medium quality and it may be economically unviable to remanufacture them. It is assumed that there is enough demand in the primary market so that all manufactured products will be sold. However, for remanufactured and refurbished products, the probabilities of selling are expressed as decreasing (linear) functions of prices and availabilities such that not all units will be sold. The

assumption is that as the availabilities increase, the probabilities of selling individual items will decrease. Though the probabilities are decreasing functions of prices and availabilities, demands are decreasing functions of prices and increasing functions of availabilities. It is assumed that an unsold remanufactured product can always be sold at the price of a refurbished product, and an unsold refurbished product has to be disposed of at a certain cost. Given the problem definition, the objective is to determine the prices of the remanufactured and refurbished products such that the total revenue is maximized.

## MODEL FORMULATION

Before describing the model, let us introduce the following notations.

- $p_1$  price of remanufactured products
- $p_2$  price of refurbished products
- $x_1$  available units of remanufactured product
- $x_2$  available units of refurbished product ( $> x_1$ )
- $X_1$  remanufacturing capacity of the manufacturer
- $X_2$  refurbishing capacity of the manufacturer
- $K_i$  sensitivity parameters ( $> 0$ ) ( $i = 1, 2, 3$ )
- $d$  cost of disposal of a refurbished product
- $R$  expected revenue from remanufactured and refurbished products

In this model, the probability of selling of a remanufactured product is given by  $(1-(p_1/P_1))(1-(x_1/K_1X_1))$  where  $P_1$  is the maximum price that can be charged at which the probability of selling becomes zero. Hence, demand or the expected number of units of remanufactured product sold is given by  $(1-(p_1/P_1))(1-(x_1/K_1X_1))x_1$ . It is seen from the expression that demand is a linearly decreasing function of price for a given number of available remanufactured units. Also, it can be shown that demand is a concave function of availability for a given price and the maximum of the function occurs at  $K_1X_1/2$ . If we restrict  $K_1 \geq 2$ , we can ensure that within the range of  $x_1$  demand is an increasing function of availability with decreasing returns to scale, which means demand grows more rapidly with availability in the initial phase of introduction of remanufactured products. But the growth rate tapers off as more and more remanufactured products become available in the market [13].

To model the probability of selling of refurbished products, the same logic can be applied. However, there is an issue that needs to be addressed. According to the problem definition, an unsold remanufactured unit can be disposed of at the price of a refurbished unit, and hence this would impact the probability of selling of refurbished products. From the expression for demand for remanufactured products, it is seen that the number of unsold remanufactured products increases linearly with price, but exponentially with availability. Hence, the impact of availability of remanufactured products would be much more effective than the impact of their price on the probability of selling of refurbished products. In fact, it is assumed that the increase in the number of unsold remanufactured units due to increase in its price is absorbed by the manufacturer by bundling the units with separate service provisions. The effective prices of remanufactured units thus sold approximately equal those of refurbished units, and the attractive offers are promptly lapped up by customers. Since the prospective customers of refurbished units are price-sensitive and they look for cost-effective utilization of these products. It can be assumed that the increase in price of remanufactured units would virtually have no impact on the probability of selling of refurbished units. On the other hand, the increase in availability of remanufactured units would definitely have an impact. Accordingly, the probability of selling of refurbished products is defined as  $(1-(p_2/P_2))(1-(x_2/K_2X_2))(1-(x_1/K_3X_1))$  where  $P_2 (< P_1)$  is the maximum price that can be charged.  $K_3 \geq K_1$  means thereby the availability of remanufactured products would impact the probability of selling of remanufactured products more than the probability of selling of



refurbished products, which is consistent with the situation. Hence, demand or the expected number of units of refurbished product sold is given by  $(1-(p_2/P_2))(1-(x_2/K_2X_2))(1-(x_1/K_3X_1))x_2$ . Following the same logic as in the case of remanufactured products, here also if we restrict  $K_2 \geq 2$ , we can ensure that within the range of  $x_2$  demand is an increasing function of availability with decreasing returns to scale [13].

Now,  $R$  can be expressed as follows:

$$\begin{aligned} R = & \left(1 - \frac{p_1}{P_1}\right) \left(1 - \frac{x_1}{K_1 X_1}\right) x_1 p_1 \\ & + \left[1 - \left(1 - \frac{p_1}{P_1}\right) \left(1 - \frac{x_1}{K_1 X_1}\right)\right] x_1 p_2 \\ & + \left(1 - \frac{p_2}{P_2}\right) \left(1 - \frac{x_2}{K_2 X_2}\right) \left(1 - \frac{x_1}{K_3 X_1}\right) x_2 p_2 \\ & - \left[1 - \left(1 - \frac{p_2}{P_2}\right) \left(1 - \frac{x_2}{K_2 X_2}\right) \left(1 - \frac{x_1}{K_3 X_1}\right)\right] x_2 d. \end{aligned}$$

The objective is to maximize  $R$  given that  $p_1$  ( $p_2$ ) lies between 0 (0) and  $P_1$  ( $P_2$ ). It can be shown that if  $d$  is less than  $P_2$ , the value of the objective function can always be improved by making the prices satisfy their lower bounds and  $p_1$  satisfy its upper bound. However, the same cannot be inferred for the upper bound of  $p_2$ , and derivation of the condition under which  $p_2$  satisfies its upper bound is not straightforward. Hence, the concavity of the objective function is to be checked and the optimal values of  $p_1$  and  $p_2$  are to be determined, and if  $p_2$  exceeds  $P_2$ , it is set  $p_2 = P_2$  [13]. In practice, disposal of a refurbished product usually does not bring a cost, instead some revenue occurs due to the selling of its scrap. Thus, by incorporating this case into the last part of the objective function (as a positive contribution), we can have a more realistic model for revenue optimization.

## NUMERICAL EXAMPLE

Currently there is a manufacturing base for notebook (laptop) computer makers in Turkey. Some of these devices are being imported as well. There are also organized collection programmes and recyclers of used notebooks. Customers usually exchange their old notebooks for newer models at the dealers' or service providers' facilities. Dealers, authorized by the manufactures, then sort the used notebooks based on their age and quality, and accordingly either upgrade or repair. The upgraded notebooks are sold through the same sales channels as the new ones with the same warranty but at a reduced price. The repaired notebooks, on the other hand, are sold through different sales channels in the markets for used notebooks at substantially reduced prices without any warranty. The price-quality differentials between upgraded and repaired notebooks make these two markets independent of each other in the sense that a quality-conscious buyer of upgraded notebooks will never look for a lower-quality repaired notebook and a price-sensitive buyer of repaired notebooks cannot afford to buy a higher-priced upgraded notebook.

Casper Computer is one of the leading notebook manufacturers in the country. The selling price of a new average capacity notebook is around \$ 1200 (vat included). Upgraded versions of secondhand notebooks of this kind are sold at \$ 1000, whereas the price for repaired secondhands is just \$ 700. Those secondhand notebooks that cannot be upgraded or repaired are disposed as scrap. Scrapped notebooks are recycled (recovered) at around \$ 150 each. Capacity of the manufacturer for both upgrading and repair operation is 500 units. Given the above information including the sensitivity parameter values as 1, 2, 3, and the available units of upgraded and repaired notebooks as 100 and 200 respectively, the proposed (modified) pricing model can be used for determining optimal prices for upgraded and repaired secondhand notebooks and the expected revenue thereof.

The model parameters and their values are stated below.

$P_1$ : \$ 1000                       $P_2$ : \$ 700                       $d$ : \$ 150                       $X_1 = X_2 = 500$   
 $x_1$ : 100                       $x_2$ : 200                       $K_1=1, K_2=2, K_3=3$

When we run this nonlinear model with the given data, we reach at the following optimal result.

**Optimal prices  $p_1$ : \$ 812.608                       $p_2$ : \$ 625.225                      Maximum revenue: \$ 1.0304E+5**

Of course, expected revenue can vary against alternative values of model parameters ( $P_1, P_2, d, X_1, X_2, x_1, x_2, K_1, K_2, K_3$ ). According to the changing conditions (with specific sets of data) the model can be used dynamically to determine the new prices to be charged and the expected revenue thereon. When the model is run for different values of parameters for any case, the following decisions are to be derived [13]. As the maximum price increases, the probability of selling at a given price and availability also increases, thereby the expected revenue increases with the maximum price that can be charged. The expected revenue increases with  $x_1$ . Since according to the assumption made in the model, the unsold upgraded products can at least be appraised at the price of repaired products, it is expected that the revenue will increase with the availability of remanufactured products.

The expected revenue also increases with increase in  $x_2$ . With increase in the availability of repaired products, more are more of the same will have to be disposed of, which will slightly increase the revenue. We can infer that as the ratio  $x_1:x_2$  improves, the revenue is also expected to increase. The expected revenue increases with increase in the disposal value, which is obvious from the model.

It is evident that as the value of  $K_i$  ( $i = 1,2,3$ ) increases, the expected revenue also increases.  $K_i$  represents the sensitivity of selling probability to availability. As  $K_i$  increases, the selling probability becomes less sensitive to availability, and as a result demand, and hence the expected revenue, increases. In particular,  $K_3$  represents the sensitivity of selling probability of repaired products to the availability of upgraded products. With increase in  $K_3$ , the selling probability of repaired products becomes less sensitive to the availability of upgraded products, which results in higher expected revenues [13].

It is assumed in the model that the probability of selling was a linear function of price, given availability. A sensitivity analysis was performed by Mitra [13] on the developed non-linear analytic model by making the probability of selling a concave function of price for a given number of available units. It resulted such that when the price was on the lower side, the probability of selling decreased slowly with increase in price, but when the price was on the higher side, the probability of selling declined sharply with price increase.

## CONCLUSION

Product recovery is one of the reverse logistics activities, which has gained importance in recent years due to government legislations and increasing awareness among people to protect the environment and reduce waste. Researchers have put in a lot of effort so far for developing inventory models in the context of reverse logistics. In all these models it was implicit that recovered products (basically the remanufactured ones) were sold along with new products in the primary markets at a price equal to or less than that of new products to satisfy customer demand. Cost minimization rather than profit maximization has become the objective of these reverse logistics inventory models. Whereas, the sale of recovered products was not so easy because of two reasons. First, customers were skeptical about the quality of recovered products, which limited the purchase of all these ones. Second, due to different quality levels of recovered products, it was expected to set different prices on these products in the secondary markets. Thus, revenue management for recovered products appeared to be an important subject, which has not been looked into so far. In this paper, we have discussed the matter in the context of recycled notebooks in Turkey, with numerical example, to maximize the expected revenue. We have selected two quality levels for illustration, namely upgraded and repaired products. The model can be generalized for any number of quality levels, though with an increase in complexity of the problems.

In the context of the notebook computer industry, when the average replacement period of notebooks is decreasing very rapidly due to introduction of newer models, the market will be swamped with quite new laptops of sufficiently high grade of quality, which can be easily upgraded and resold in the primary and secondary markets. This is also true for other type of recyclable products, i.e., photocopiers, mobile phones, white goods, television sets, etc. This means huge business opportunity for the original equipment manufacturers as well as the third-party remanufacturers. Thus, as product recovery activities get intensified, revenue management programs will be needed more.

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# INTRA-CITY BUS PLANNING USING COMPUTER SIMULATION

Reza AZIMI<sup>1</sup> and Amin ALVANCHI<sup>2</sup>

**Abstract** — Urban planning is an important issue with great impact on general welfare. Stochastic parameters such as passengers' arrival times, trip durations, vehicle breakdown, accident probability, and vehicle and drivers' capabilities contribute to many urban planning problems such as subway planning, traffic flow planning, governmental services planning and bus route planning. These parameters make most problems too complicated and using common optimization methods cause difficulty in these cases. Computer simulation is a powerful tool that can be employed for solving these kinds of urban planning problems. In this paper, actual planning of bus routes in the city of Edmonton using computer simulation is presented. The proposed simulation model offers a helpful decision support tool for high level city decision makers.

**Keywords** — Bus Route Planning, Discrete Event Simulation, Urban Planning

## 1. INTRODUCTION

Urban management and planning is an important issue for all governments whose target is to provide better urban services in order to meet citizens' needs. Simulation is a powerful tool that has been deployed for urban management and planning in many cases, such as subway planning, traffic flow planning, government service planning, and bus route planning, based on its capabilities to model and consider stochastic parameters like passengers' arrival times, traffic jams, accident probabilities and so on. [1-4].

This paper addresses a project carried out to create all necessary elements for modeling an intra-city bus line using **Special Purpose Simulation (SPS) Modeling** and implementing it in an actual case study. SPS modeling enables a practitioner, who is knowledgeable in a specific domain but not necessarily in simulation, to model a project within that domain in which graphical representations, navigation schemes, specification of model parameters, and representation of simulation results are completed in a format native to the domain itself [5]. For this purpose, we used the Symphony.NET platform developed by the Hole School of Construction Engineering and Management at the University of Alberta. Symphony.NET allows for the creation of new SPS tools in the form of modeling element templates.

## 2. PROBLEM DESCRIPTION AND OBJECTIVES

This project was initiated to analyze intra-city bus routes and to provide a decision support tool for city decision makers debating how many buses should be employed for concurrently offering satisfactory services for intra-city passengers in the region while maximizing long term profit. The number of passengers transported is directly related to the number of buses employed. On the other hand, as the government spends quite a bit of money to subsidize city bus transportation, a tradeoff should be reached to determine the number of buses in each route. Each route has its own characteristics: length, number of stations (bus stops), number of passengers getting on and off at each station, speed limit, and so on. This means that each route is composed of deterministic and stochastic variables and combining them for modeling purposes requires special tools. The Discrete Event Simulation method has been utilized in this project due to its capabilities regarding this issue.

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This project involves two phases: in Phase 1, we developed an SPS model that can be used for various intra-city bus routes and scenarios, in Phase 2, a specific city bus route, Edmonton bus route number 6, is simulated and analyzed for six different scenarios.

### 3. MODEL CONCEPTUAL ARCHITECTURE

A typical bus route is a combination of different elements interacting with each other to form a system. Buses, streets, intersections, stations, passengers and their property are the main elements for the bus route system.

A bus route can be presented as a directed cyclic network in which street takes the role of network line or edge and intersections and stations have the role of nodes or vertices. Therefore, every bus route can be envisioned as a combination of the straight streets/roads that have been connected to each other through intersections and stations (Figure 1).

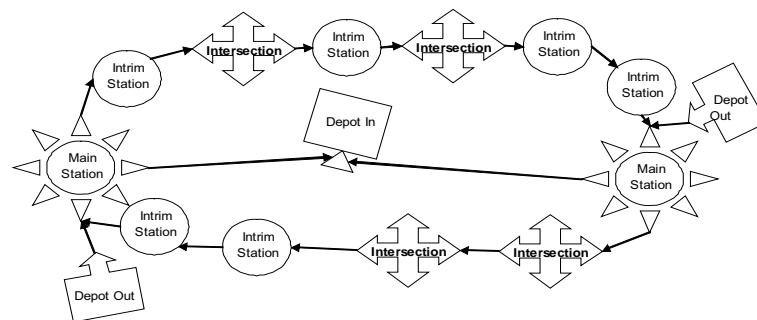


FIGURE 1. Typical bus route network

Stations are the places where the passengers can get on or get off of the bus. Every bus route has at least two main stations where buses start and finish their daily trips. These stations are generally located at the different corners of the route and will be assumed as the endpoints of each route direction. Time is set in these stations, drivers changes happen in these stations and a large portion of the bus passengers will get off and get on the bus in these stations. Passenger arrival rates (demand for service) at each station will differ according to time of day and day of the week.

There are also some interim stations in each bus route. These stations are generally less crowded than the main stations. Intersections are the points at which buses should stop if the light is red and should pass if the light is green. No passenger or driver exchange or extra stops should happen in the intersections. Roads are determined to be straight line streets of a certain length. Each road might have its own regulation for speed limit and also traffic flow will affect the mean of the speed with which bus travels along the road. There may be a bus breakdown or a bus accident in the road which will cause a sudden stop for the bus. There should be also some places designated where buses come from at the start of service and return to when their service time is over.

#### Stations (bus stops) Element

A Station (bus stop) is a designated place where a public transport bus stops for the purpose of allowing passengers to board or leave the bus. For simulation purposes, Station is defined as a user element. It has the following attributes: “Get on” attribute (considers the number of passengers normally expected to get on a bus at a certain station at different times, which can be defined as distribution); “Get off” attribute (considers the average percentage of all passengers normally intending to get off the bus at the certain station (Bus stop) at different times); “Stop duration” attribute (Stop duration depends on the number of passengers boarding or leaving the bus); and “Break time” attribute (considers coffee, lunch break, or changing the bus driver at a certain station, which usually happens at the main stations). The number of passengers who are getting on the bus, the average waiting time in the station, and the stop duration, all of which affect the cycle time of the bus, are the outputs of this element.

### Road Element

Roads have been set as a user element to allow their use in different models and places. “Length”, “Speed limit”, “Normal Speed”, “Traffic flow influence” and “Accident Probability” are the attributes for the Road element. See Figures 2 and 3.

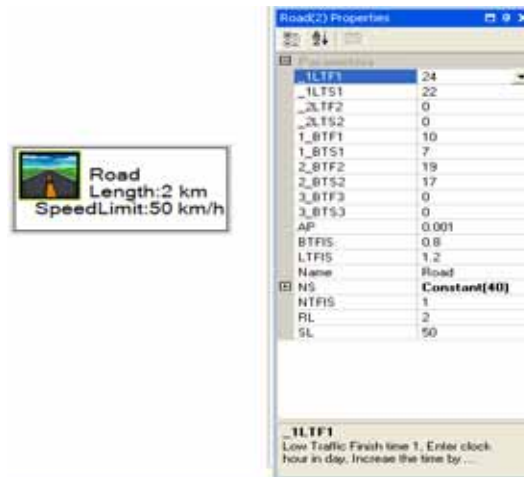


FIGURE 2. Road element and its attributes

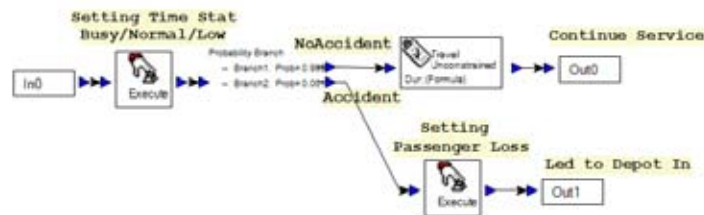


FIGURE 3. Child window of Road element

### Intersection Element

Another user element is the Intersection element. Buses should stop before intersections if the light is red and should pass through the intersection if the light is green. This element has two attributes: “Green/Red duration” and “Time to pass the intersection”. When the traffic light is green, the bus is allowed to pass through the intersection, but it will take a while for it to pass through the intersection. If the intersection is in its busy time, it will take more time for bus to pass through the intersection in comparison with the normal or low traffic time.

### Depot Out Element

Depot Out is the place where the buses enter the bus route system. Three attributes have been generated for the Depot Out element: “Number of Buses” to be generated (NBus), “Time Between Buses” to be generated (BT), “Total Capacity of each bus” (Capacity).

### Depot In Element

Depot In is the place where buses go to when exiting the bus route system due to accident, breakdown, or finishing service time. Depot in has the capability of gathering the number of passengers served. Two attributes have been defined for the Depot In element: “Total Passenger Served” (TPS) and “Total Passenger Lost /missed” (TPL)

## 4. USER ELEMENT DEVELOPMENT

According to the conceptual architecture, five user elements were built to be used in the bus route system. These elements were designed and developed to be capable enough to support all similar bus route models by using only some simple customization for each model. Figure 2 shows the Road element as an example, and Figure 3 shows the simulation model for that element.

## 5. CASE STUDY

Edmonton’s bus route number 6 was selected to be simulated and analyzed as the case study. Information regarding passengers’ arrival times (demand) at different times of day at different stations, rush hours, specifications of different intersections, and so on, was gathered to be used in the simulation model. (Table 1, 2, &3)

TABLE1. Data gathered for stations along Route 6

	Millgate	Southgate	...	University	Southgate
Station Code	A	B	...	CR	BR
Rush Hours	As in default*	As in default	...	As in default	As in default
Un-crowded Time	As in default**	As in default	...	As in default	As in default
Passenger Arrival in Rush hours	0.5 minute	1.5 minutes	...	0.5 minutes	1.5 minutes
Passenger Arrival in Normal Times	1 minute	3 minutes	...	2 minutes	3 minutes
Passenger Arrival in Low Traffic Times	3 minute	8 minutes	...	10 minutes	8 minutes
Probability that passengers get off	95%	10%	...	30%	30%

\* From 7 am to 8.5 am, 11 am to 1 pm and 4 pm to 6 pm

\*\* From 6 am to 6.5 am , 2 pm to 3:30 pm and 9 pm to 12 am

The model was created to consider six different scenarios for Route 6. In the first scenario, there are two buses available. The first one heads to the Millgate station at 6:00 am while the second one heads to Downtown station at the same time, both buses provide services until 12:00 am. For the second scenario, 4 buses are available, two of them head to the Millgate Station and the Downtown station at 6 o’clock in the morning, and the others head to the same stations 15 minute later. The other scenarios are:

- Scenario#3: Starting from 6:00 am, 3 buses head to the Millgate station (1 bus/15 min) and 3 buses head to the Downtown station (1 bus/15 min).
- Scenario#4: Starting from 6:00 am, 4 buses head to the Millgate station (1 bus/15 min) and 4 buses head to the Downtown station (1 bus/15 min).
- Scenario#5: Starting from 6:00 am, 5 buses head to the Millgate station (1 bus/15 min) and 5 buses head to the Downtown station (1 bus/15 min).
- Scenario#6: Starting from 6:00 am, 6 buses head to the Millgate station (1 bus/10 min) and 6 buses head to the Downtown station (1 bus/10 min).

For all the scenarios, the service time is from 6:00 am to 12:00 am.



TABLE 2. Gathered Data for different intersections along Route 6

	99St 51Av	...	99St 82Av
Location	Between A and B	...	Between C and D
Intersection Code	IntAB1	...	IntCD2
High traffic times	As in default*	...	As in default
Low Traffic Time	As in default**	...	As in default
Red Duration in Busy Hours	2	...	2
Green Duration in Busy Hours	2	...	2
Red Duration in Normal Hours	1.5	...	1
Green Duration in Normal Hours	1	...	1
Red Duration in Low traffic Hours	0.5	...	0.5
Green Duration in Low traffic Hours	0.5	...	0.5
Time to pass through inter section in busy hours (Minute)	Normal (0.3,0.1)	...	Normal (0.3,0.1)
Time to pass through inter section in Normal hours(Minute)	Normal (0.2,0.1)	...	Normal (0.2,0.1)
Time to pass through inter section in Low traffic hours(Minute)	Const (0.1)	...	Const (0.1)

\* Default times for High traffic times in intersections are: From 7 am to 10 am and 5 pm to 7 pm

\*\* Default times for Low traffic times in intersections are: From 10 pm to 12 am

TABLE 3. Gathered Data for different roads along Route 6

	51Av/76St-99St	...	99st/83Av-104Av/100St
Location	Between A and IntAB1	...	Between D and E
Road Code	RAB1	...	RDE1
Length (km)	1	...	3
Busy times	As in default*	...	As in default
Low Traffic Time	As in default**	...	As in default
Speed limit (km/h)	50	...	50
Normal Speed (km/h)	Norm (40,5)	...	Norm (45,5)
Accident Probability	%0.01	...	%0.01
Busy Time Influence on Speed	0.9	...	0.8
Normal Time Influence on Speed	1	...	1
Low Traffic Time Influence on Speed	1.2	...	1.2

\* Default times for Busy traffic times in roads are: From 7 am to 10 am and 5 pm to 7 pm

\*\* Default times for Low traffic times in roads are: From 10 pm to 12 am.

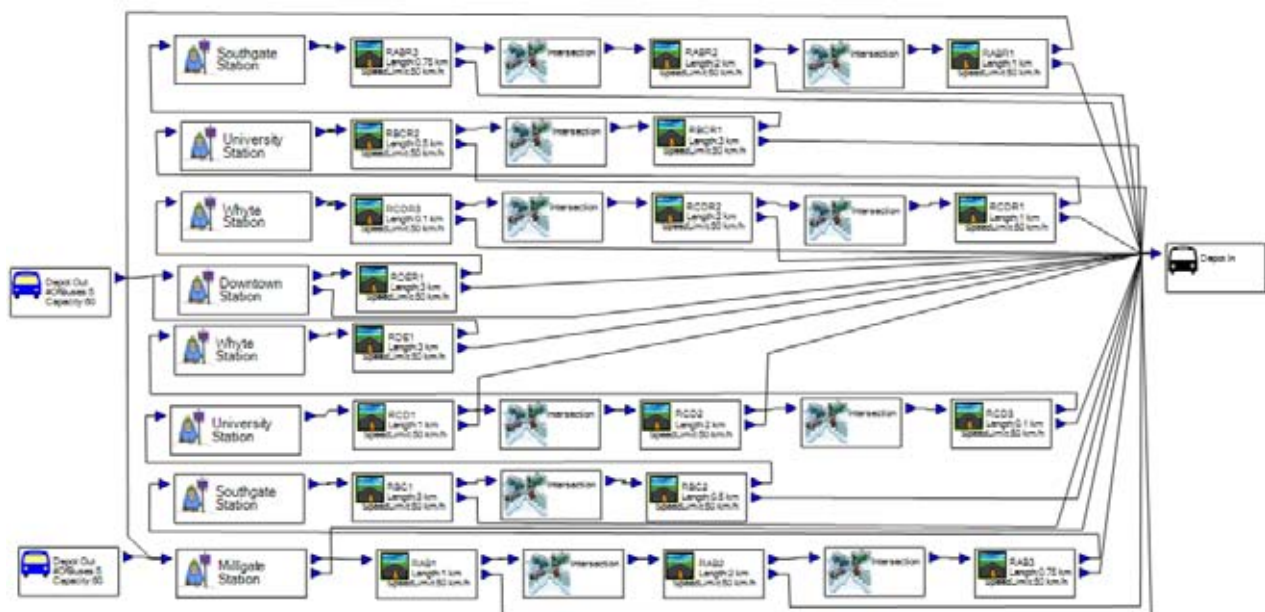


FIGURE 4. Simulated model of the route 6

In terms of analyzing these scenarios, different items such as daily bus drivers' Wages (DW), Bus Leasing Cost (BLC), Bus Maintenance Cost (BMC), Total Overhead cost (OH), Fare and Missed income due to missed passengers (Including for both accidents and extra waiting times) have been taken in consideration.

Table 4, represents the outputs of the simulation model for different scenarios. (Numbers have been scaled due to confidentiality reasons).

TABLE 4. Outputs of the simulation model for different scenarios

Scenario	1	2	3	4	5	6
Total Buses in Service	2	4	6	8	10	12
Total Passenger Served	1595	2015	2350	2805	3150	3220
Total Income (From Fares)	3190	4030	4700	5610	6300	6440
Total Daily Cost*	4905	4972	5856	7260	8587	9934
Net Profit (Loss)	-1715	-942	-1156	-1650	-2287	-3494

\* Including: drivers' wage cost, maintenance, overhead, and passenger missed

Based on the results, the second scenario creates the best financial outcome, although the city still loses some money while providing transportation service for the people.

## 6. CONCLUSION

Modeling and optimizing complicated transportation problems containing stochastic variables requires a powerful tool and the simulation method is one of the most efficient methods for dealing with these kinds of problems. Key issues for successful simulation include the acquisition of valid source information about the project, selection of key characteristics and behaviors, the use of simplifying approximations and assumptions within the simulation, and fidelity and validity of the simulation outcomes.

At the end we can say that the simulation method is very useful especially in a repetitive process in which manual calculations and/or observations for different scenarios are difficult, expensive, time consuming, and error-prone.

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# **Chapter 9**

Planning, Operations, Management and Control of Transport  
and Logistics



# A REVIEW OF TIMETABLING AND RESOURCE ALLOCATION MODELS FOR LIGHT-RAIL TRANSPORTATION SYSTEMS

Selmin D. ÖNCÜL<sup>1</sup>, D. Selcen Ö. AYKAÇ<sup>2</sup>, Demet BAYRAKTAR<sup>3</sup> and Dilay ÇELEBİ<sup>4</sup>

## Abstract

*This paper surveys the relevant operations research literature on timetabling and resource allocation problems with a special attention paid to the transportation systems. The purpose of this review is to define the critical objectives, determine the key components and identify the key issues for developing a comprehensive mathematical model for timetabling of light rail transit vehicles in sequence with the assignment of drivers as an available resource. In doing so, the implications of the emerging timetabling research is discussed, components of the mathematical models proposed are reviewed, and the extend they reflect real business practices are analyzed. Finally, fundamental issues and primary elements of a simple model in association with general timetabling and resource allocation problems are presented.*

**Keywords:** Timetabling, resource assignment, light-rail transportation, quantitative models

## 1. INTRODUCTION

This research focuses on public transportation, since it is important to raise the capacity of public transportation and quality of service at reasonable cost, in order to prevent problems caused by individual means of transport such as pollution, congestion and social discrimination [1].

The most essential schedule of transportation systems is the timetable [20]. Constructing a timetable is part of the overall transit planning process, a choice of service frequency for each route, and allocations of vehicles and crews to routes [25]. For example a train timetable defines the planned arrival and departure times of trains to/from yards, terminals and sidings, and train scheduling plays a vital role in managing and operating complex railroad systems [33]. Several approaches have been used to solve timetabling problems up to now. Simulation [21], [30], linear programming [29] and metaheuristics [20] are used for railway timetabling. Evolutionary algorithms have been applied with very good results to various types of timetabling problems [2], [10], [15], [8], [4]. Also, metaheuristics have become increasingly popular in the field of automated timetabling [20],[22].

In this paper, the scope is preparing a model for timetables and assignment of resources (trains and operators) for light rail transit vehicles. Timetabling and crew scheduling are major planning problems for railway companies at operational and short-term level [19]. This paper is concentrated on, only operational level timetabling and resource assignment problems. Moreover, only models and techniques used in passenger transportation which is completely different from freight transportations are focused on.

## 2. LITERATURE REVIEW

Timetabling is the process of assigning events, and resources, to timeslots subject to constraints [33],[6]. Most of the time-tabling problems belong to the class of NP-hard problems, as no deterministic polynomial algorithm exists [10]. Large variety of solving techniques has been tried out in literature for solution of timetabling problems [7].

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Personnel scheduling problems involve the allocation of staff to timeslots and possibly locations [32]. Personnel scheduling covers many areas, such as the nurse rostering [5], transportation staff scheduling [33], educational institute staff scheduling [24] and airline crew scheduling [14].

### 2.1. Timetabling

The tasks of public transportation are to meet the increasing demands of all kinds of passengers by high quality of service based on limited number of vehicles [11]. Up to now, for the solution of timetable scheduling problems, simulation [21], [30], simulated annealing [27], genetic algorithms [2], tabu search [10], hybrid genetic algorithms [11], linear programming [29], integer programming [16], heuristics [18] and mixed-integer programming [31] methods have been used.

On the other hand, the studies made for personnel scheduling studies are generally based on fixed schedule assumption and make resource scheduling accordingly [23], [11], [3], [17], [16], [13]. These personnel scheduling problems involve the allocation of staff to timeslots and possibly locations.

There is limited literature which solves timetable scheduling and resource assignment problem interactively. There are three studies which propose timetabling together with consideration of resource constraints. (1) Cowling et al. [12] developed a hyper-GA for scheduling geographically distributed training staff and courses. They aimed to maximize the total priority of courses which are delivered in the period while minimizing the amount of travel for each trainer. (2) Sigl et al. [28] determined the quality of timetable by earliness of scheduled classes. Here, a genetic algorithm is employed to schedule classes as early in the morning as possible, while minimizing the number of holes in a student's schedule. Minimizing the number of conflicts is achieved by number of conflict by a large number  $K$  and then selecting the best individuals in a population according to smallest fitness value. Instructors and rooms are considered as hard constraints. (3) Walker et al. [31] developed a recovery model which involves two related processes: (a) determination of a revised or amended train schedule; (b) involving the adjustment or repair of the associated driver duties. Their model's objective is to minimize deviation from the existing schedule while incurring as little cost increase as possible. Their research is mainly about short-term level timetabling. For this purpose, an integer programming model is developed to resolve disruptions to an operating schedule in the rail industry. The model constrained with two distinct blocks, with separate variables and constraints. These blocks are coupled by piece of work sequencing constraints and shift length constraints which involve variables from both blocks.

In this paper, the timetabling problem is modeled simultaneously with resource assignment problem. The constraints and demand structure is different and specific to the problem area, which is light-rail transportation.

## 3. FUNDAMENTAL ISSUES OF PROPOSED MODEL

Modeling focuses on an operational-term timetabling of light-rail transit considering double track, with a number of intermediate stations in between. The operational and physical constraints are defined to reflect the real world applications. Therefore, in addition to literature driven criteria, model development stage has also employed information provided by the operators of the light-rail transportation system of Istanbul.

The purpose is set as: "to develop optimal timetables and personnel schedules for light-rail transit". The system is composed of two sub-problems: the timetable problem and personnel scheduling problem. A model, with an objective of minimizing average passenger travel time and minimizing number of trains required, is developed.

### 3.1 Model Parameters

- Number of vehicles: Total number of vehicles available for timetabling [32].
- Vehicle capacity: Passenger capacity of vehicle.
- Trip start and finish hours
- Number of machinists
- Maximum daily working hour of machinists
- Maximum duration that a machinist can be on train.
- Headway time: Minimum time difference between the departure of train from a station and arrival of next train to the same station [32].
- Minimum dwell time of stations: Minimum dwell times changes for each station
- Maximum dwell time of stations: Maximum dwell times changes for each station

- Minimum run time: Minimum time that a train needs to cover distance between two stations because of speed limits [26].
- Inflow of passengers: Number of passengers coming to a specific station between specific time intervals.
- Outflow of passengers: Number of passengers leaving a specific station between specific time intervals.
- Constant multipliers for average travel time and train number.
- Number of machinists: Available maximum machinist number as full time/part-time.

### 3.2. Model Variables

- Train index: Train index increases for each trip [32].
- Station index: Station index shows the sequence of stations according to path of trains [33].
- Trip start time of train: Time that a train start it's trip.
- Arrival time of train: Arrival time of a train to a specific station [33].
- Departure time of train: Departure time of a train from a specific station [33].
- Run time: Travel time of train between two stations [20].
- Passenger travel time: Duration of a passenger's time on train [9].
- Number of passengers at station: Number of passengers at a specific station for a specific time interval.
- Number of passengers on train at a station: Number of passengers on train at a specific station for a specific time interval.
- Binary variable for assignment of machinists: This variable takes value 1 is machinist is assigned to a train, 0 otherwise.
- Trip duration: Duration of trip for each train.
- Total working hour of each machinist: Total duration of machinist at work.
- Total driving hour of each machinist: Total duration of machinist on train for each day.
- Required machinist quantity for each day: Machinist quantity changes according to number of trips scheduled.

### 3.3 Model Constraints

Previous literature discussed in the above sections have suggested certain constraints specific to rail transportation models. In addition, interviews with IBB light-rail system operators have proposed consideration of specific criterias.

1. Number of passengers on train at a specific time interval must be smaller than the maximum passenger capacity of train.
2. The departure time of first train from the first station must be greater or equal to start hour of trips.
3. Arrival time of final train to the final station at final trip must be smaller than finish hour of trips.
4. The time difference between departure and arrival of a train at a specific station must be greater than minimum dwell time and must be smaller than maximum dwell time.
5. A train's arrival time to a station must be greater or equal to the time of departure from the previous station plus headway time.
6. Travel duration between two stations must be greater than minimum travel duration between stations according to speed limits.
7. Travel time of a passenger is equal to run time of train between stations plus time difference between arrival time of passenger to the station and arrival time of train to the station.
8. Total working hour of each machinist must be smaller than maximum daily working hour.
9. Total driving hour of each machinist must be smaller than maximum daily driving hour.
10. When a machinist is assigned to a trip it could not be assigned to the following trip on the same train.
11. Total trip duration for each trip is equal to time difference between arrival time of train to final station minus departure time of train from the first station.
12. Total driving hour for each machinist is equal to sum of total trip durations times binary variable about assignment of related machinist.

13. Total working hour of each machinist is equal to total driving hour of each machinist plus walking durations to the trains plus rest hours such as lunch, coffe breaks.
14. Total Passenger quantity on train, at specific station for a specific time interval equal to passenger quantity on train at previous station plus inflow of passenger to the station minus outflow of passengers from the station.

### 3.4 Critical Objectives

The time a passenger spends waiting is a very critical element for evaluating passenger service level. Typically, a railway passenger faces different types of waiting due to different causes. For instance, when connections are not properly scheduled, a passenger will have to wait a long time between trains. Trains running behind schedule will also create waiting times. During rush hours most of the trains meet with some considerable delay. Thus, an actual travel time take during rush hour is typically longer than the ideal running time [29].

The objective of the model is to minimize the average travel time of passenger(s) and minimize number of trains.

- Objective: Minimize average travel time of passenger(s) times constant multiplier 1 plus number of trains times constant multiplier 2.

### 3.5 Assumptions

1. The Demand data is measured at certain time-intervals so the trip frequency is determined at this frequency.
2. Waiting time at platforms are decided according to number of passengers. There must be upper and lower limits for waiting times at stations.
3. The vehicles must stop at all intermediate stations. The dwelling time among every station might not be same. The length of dwelling time depends on predicted volume of passenger flow (Chang and Chung, 2005).
4. It is assumed that machinists should not make two consecutive trips.
5. It is assumed that passengers arriving to the stations will take the first train

## 4. CONCLUSION AND FUTURE WORK

It is obvious that, nowadays, efficient public transportation is a critical task for metropolises. Yet, previous research that considers resource assignments in timetabling is limited. This paper has developed a model that includes the critical objectives and key components specific for timetabling of light rail transit vehicles. Simultaneously, assignment of machinist has also been considered. It has been revealed that light-rail transportation has its own set of constraints such as headway and dwell times. In addition, there are other human factors such as machinist rest hours and unavailability for consecutive rides. It was uncovered that the objective function should include both the service level objective (minimizing passenger travel time) and the operational objective (minimizing the number of trains).

Future research should focus on solving the model, validating the model via simulation and verifying the results.

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# AN APPROACH OF INTEGRATED LOGISTICS HMMS MODEL UNDER ENVIRONMENT CONSTRAINTS AND AN APPLICATION OF TIME SCALE

*Fahriye Uysal<sup>1</sup>, Ömür Tosun<sup>2</sup>, Orhan Kuruiüzüm<sup>3</sup>*

**Abstract** —Concern for the environment has led many firms to define policies that protect the environment within which they operate. This concern is reflected in all the activities of the product life cycle, both in those of direct logistics as well as reverse logistics. The aim of the paper is to investigate how environment policies, in the form of emission charges or emission limits, affect the logistics decisions of a firm. Time Scale calculus is used to analyze the integrated logistics model of HMMS under environment constraints.

**Keywords** —Integrated Logistics, Reverse Logistics, Time Scales

## INTRODUCTION

With the increased environmental concerns and stringent environmental laws, integrated logistics has received growing attention throughout this decade. Integrated logistics includes the planning, implementation, and control of the flow and storage of raw materials, in-process inventory, finished goods, services, related information, and payments among suppliers and consumers from the production of raw materials to the final recycling or disposal of finished goods [1]. The integrated logistics process features are inbound logistics, manufacturing logistics, outbound logistics. In this study the integrated logistics is considered in two stages, forward and reverse logistics. Whereas forward logistics is generally the movement of product from one origin to many destinations, the reverse movement of a product is the opposite, from many origins to one destination.

Reverse logistics can be defined as the process of moving goods from their typical final destination for the purpose of capturing value, or proper disposal [2]. Moving goods from their point of origin towards their final destination has been the focus of logistics systems. A reverse logistics system incorporates a supply chain that has been redesigned to manage the flow of products or parts destined for remanufacturing, repairing, or disposal and to effectively use the resources [3].

The reasons behind promoting integrated logistics practices are of both economic and environmental kind. Among the economic motives we find the recovery of the value still incorporated in the used product and the important savings in material and components. From the environmental viewpoint, we might cite concern regarding solid waste pollution [4], landfill saturation [5] or the scarcity of raw materials [4], [6].

## THE MODEL

The integrated logistics model is considered in two stages. The first stage is forward logistics, whereas the second one is the reverse logistics (Figure 1).

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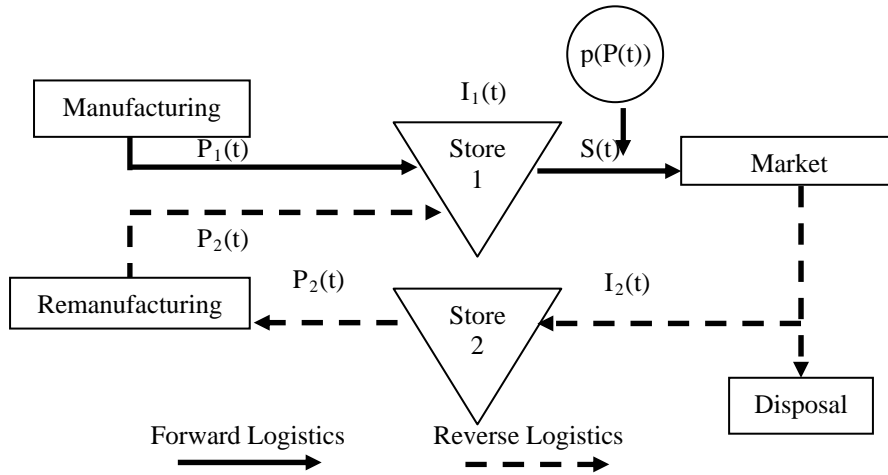


FIGURE 1  
Integrated Logistics Material Flow of the Model

HMMS model first appeared in the book by Holt, Modigliani, Muth and Simon [7] in the discrete version. In [8], the author studied the continuous version of the HMMS model by taking nonnegative discount rate ( $\alpha$ ) into account.

Time scale calculus is a new and exciting mathematical theory first introduced by Stefan Hilger in his Ph D. thesis [9], which unites two existing approaches to dynamic modeling – difference and differential equations – into a general framework called dynamic models on time scales. Since time scale calculus can be used to model dynamic processes whose time domains are more complex than the set of integers or real numbers, dynamic modeling in economy will provide a flexible and capable modeling technique for economists [10].

Where the quantities are defined as

$C_p$  = regular time cost per unit

$P_{it} / P(t)$  = production rate at time  $t$  (state variable)  $i = 1, 2$

$\hat{P}(t)$  = production rate goal level at time  $t$

$C_I$  = cost of holding a unit for one period of time

$I_{it} / I(t)$  = inventory level at time  $t$  (control variable)  $i = 1, 2$

$\hat{I}(t)$  = inventory size goal level at time  $t$

$S_t / S(t)$  = demand rate at time  $t$ ; positive and continuously  $\nabla$  - differentiable

$T$  = length of planning period

$\alpha$  = non-negative discount rate, a constant

$a$  = inventory holding cost coefficient, positive constant

$b$  = production cost coefficient, positive constant

$I_0$  = initial inventory level

$\tau$  = linear charge per unit pollution

$p(P(t))$  = pollution: a convex, monotonically increasing, continuously differentiable, and  $p'$  is continuously  $\nabla$  - differentiable

In **stage 1**, pollution costs are added into the minimization of the production and inventory costs of the forward logistics.

$$\text{The Discrete Model: } C = \sum_{t=1}^T [C_p (P_{it} - \hat{P})^2 + C_I (I_{it} - \hat{I})^2 + \tau p(P(t))] \quad (1)$$

Subject to the constraint  $I_{it} = I_{it-1} + P_{it} - S_{it}$ , where  $t = 1, 2, \dots, T$

$$\text{The Continuous Model: } C = \int_0^T e^{-\alpha t} \left[ \frac{\alpha}{2} (I_1(t) - \hat{I}(t))^2 + \frac{b}{2} (P_1(t) - \hat{P}(t))^2 + \tau p(P(t)) \right] dt$$

Subject to the constraint  $I'(t) = P_1(t) - S_1(t)$ , and  $I(0) = I_0$  (2) [8]

$$\text{The Time Scale Model: } C = \int_0^{\sigma(T)} \hat{e}_{-\alpha}(\rho(s), 0) \left( \frac{a}{2} (I_1 - \hat{I})^2 + \frac{b}{2} (P_1 - \hat{P})^2 + \varphi(P(s)) \right) \nabla s \quad (3)$$

The cost given above is optimized with subject to  $I^\nabla(t) = P_1(t) - S_1(t)$  and with the initial values of  $I(0) = I_0$  and  $P(0) = P_0$ .

At this point, two cases will be considered:

**Case 1.** Let  $p(P(t)) = P$  (linear).

If the pollution function  $p(P(t))$  is linear, then the conditions of optimality will be simple. Let us assume that  $p(P(t)) = P(t)$ . The first derivative of the pollution is equal to one, and second derivative is zero.

The coefficient matrix  $A(t) = \begin{bmatrix} \frac{\alpha}{1 + \alpha v(t)} & \frac{a}{b(1 + \alpha v(t))} \\ 1 & 0 \end{bmatrix}$  is a constant matrix if  $v(t)$  is a constant, or if  $\alpha = 0$ . Otherwise  $A$  is a non-constant matrix function. For this system, we have the following statement:  $I - v(t)A(t)$  is invertible if and only if  $v(t) \neq \sqrt{\frac{b}{a}}$  for all  $t \in T$ .

$$\begin{bmatrix} P_1(t) \\ I_1(t) \end{bmatrix} = \hat{e}_A(t, t_0) \begin{bmatrix} P_0 \\ I_0 \end{bmatrix} - \int_0^t \hat{e}_A(t, \rho(\tau)) \begin{bmatrix} \frac{a\hat{I} + \alpha b\hat{P} - \alpha\tau}{b(1 + \alpha v(t))} - \hat{P}^\nabla \\ S(t) \end{bmatrix} \nabla \tau \quad (4)$$

**Case 2.** Let  $p(P(t)) = 0.5P^2$  (quadratic).

If the pollution function  $p(P(t))$  is quadratic, then the conditions of optimality will be simple. Let us assume that  $p(P(t)) = 0.5P^2(t)$ . The first derivative of the pollution is equal to  $P(t)$ , and second derivative is zero.

The coefficient matrix  $A(t) = \begin{bmatrix} \frac{\alpha b + \alpha\tau}{(b + \tau)[1 + \alpha v(t)]} & \frac{a}{(b + \tau)[1 + \alpha v(t)]} \\ 1 & 0 \end{bmatrix}$  is a constant matrix if  $v(t)$  is a constant, or if  $\alpha = 0$ . Otherwise  $A$  is a non-constant matrix function. For this system, we have the following statement:  $I - v(t)A(t)$  is invertible if and only if  $v(t) \neq \sqrt{\frac{b + \tau}{a}}$  for all  $t \in T$ .

$$\begin{bmatrix} P_1(t) \\ I_1(t) \end{bmatrix} = \hat{e}_A(t, t_0) \begin{bmatrix} P_0 \\ I_0 \end{bmatrix} - \int_0^t \hat{e}_A(t, \rho(\tau)) \begin{bmatrix} \frac{a\hat{I} + \alpha b\hat{P}}{b(1 + \alpha v(t))} - \frac{b}{b + \tau} \hat{P}^\nabla \\ S(t) \end{bmatrix} \nabla \tau \quad (5)$$

In **stage 2**, HMMS model is applied to the reverse logistics.

$$\text{The Discrete Model : } C = \sum_{t=1}^T [C_p(P_{2t} - \hat{P})^2 + C_I(I_{2t} - \hat{I})^2] \quad (6) [7]$$

Subject to the constraint  $I_{2t} = I_{t-1} + P_{2t} - S_{2t}$ , where  $t = 1, 2, \dots, T$

$$\text{The Continuous Model: } C = \int_0^T e^{-\alpha t} \left[ \frac{\alpha}{2} (I_2(t) - \hat{I}(t))^2 + \frac{b}{2} (P_2(t) - \hat{P}(t))^2 \right] dt \quad (7) [8]$$

Subject to the constraint  $I'(t) = P_2(t) - S_2(t)$ , and  $I(0) = I_0$

The Time Scale Model:  $C = \int_0^{\sigma(T)} \hat{e}_{-\alpha}(\rho(s), 0) \left( \frac{a}{2} (I_2 - \hat{I})^2 + \frac{b}{2} (P_2 - \hat{P})^2 \right) \nabla s$  (8) [10]

The above cost function is optimized with subject to  $I^\nabla(t) = P(t) - S(t)$  and with the initial conditions of  $I(0) = I_0$  and  $P(0) = P_0$ .

$$\begin{bmatrix} P_2(t) \\ I_2(t) \end{bmatrix} = \hat{e}_A(t, t_0) \begin{bmatrix} P_0 \\ I_0 \end{bmatrix} - \int_0^t \hat{e}_A(t, \rho(\tau)) \begin{bmatrix} \frac{a\hat{I} + \alpha b\hat{P}}{b(1 + \alpha v(t))} - \hat{P}^\nabla \\ S(t) \end{bmatrix} \nabla \tau \quad (9)$$

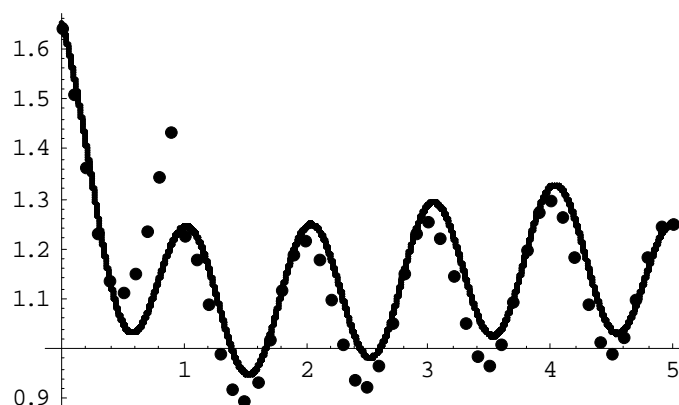
## SOLUTION OF THE MODEL

The integrated HMMS model of the reverse logistics is considered in two stages and solved with time scales analysis. Since we want to compare our results and graphs with the existing results for the time scale, R, in our model we will consider the same quantities as have been taken by [8] :

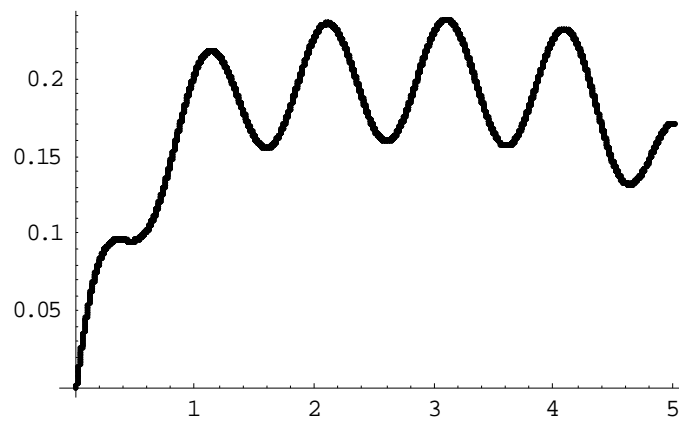
TABLE 1  
Parameter Specification for Examples

Description	Specification
Demand	$S(t) = (1 + 0.05t)(1 + 0.2 \sin 2\pi t)$
Product rate goal level	$P_1(t) = 1 + 0.05t$
Inventory size goal level	$I_1(t) = 0.2 + 0.2 \sin 2\pi t$
Production cost coefficient	$c = 4$
Inventory holding coefficient	$h = 20$
Rate of discount	$\rho = 0.05$
Pollution – linear	$P$
– quadratic	$0.5P^2$
Pollution tax coefficient	
- linear	$\tau = 40$
- quadratic	$\tau = 5$
Planning horizon	$T = 5$

Graphics of the solutions are given below. Graphic 1 and 2 are the production and inventory graphics with the linear pollution function. They represent the first stage of the reverse logistics integrated HMMS model.

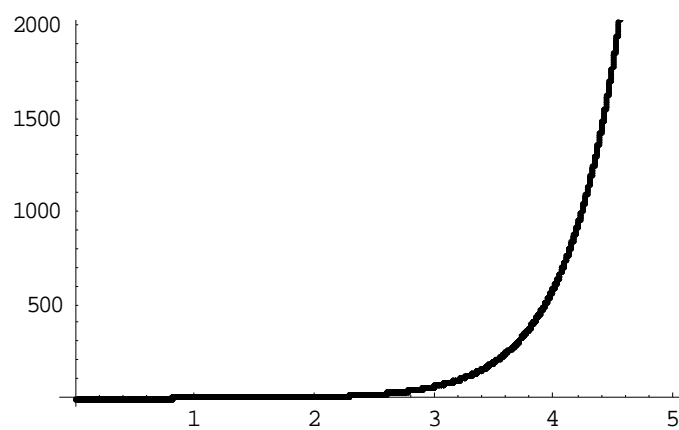


GRAPHIC 1  
The Graph of Production P(t)

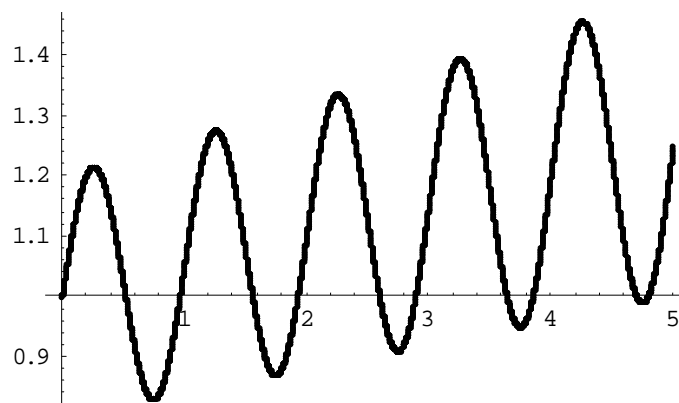


GRAPHIC 2  
The Graph of Inventory  $I(t)$

In graphic 3 and 4, the structure of the forward logistics with a quadratic pollution function is seen.



GRAPHIC 3  
The Graph of Production  $P(t)$



GRAPHIC 4  
The Graph of Inventory  $I(t)$

The two cases show, that the pollution charge in quadratic case reduces the inventory level, and the production rate is smoother than without charge.

## CONCLUSION

As it can be seen from the solution graphics, when there is a linear pollution function a direct change is seen between pollution and production and inventory costs, but when the pollution function becomes quadratic the relation in production costs becomes parabolic with  $t$ . But the changes in inventory costs are mostly in a sinusoidal structure.

The solution of the integrated logistic HMMS model proposed a social effect. This effect is more distinguished in the quadratic form than the linear form.

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# FREIGHT TRANSPORT PLANNING WITH GENETIC ALGORITHM BASED PROJECTED DEMAND

Soner HALDENBİLEN<sup>1</sup>, Özgür BASKAN<sup>2</sup>, Hüseyin CEYLAN<sup>3</sup> and Halim CEYLAN<sup>4</sup>

**Abstract-** Road freight transport needs to be estimated using the current status of the transport using the socio-economic and transport related indicators and then the planning may be carried out in order to achieve the goals of sustainable transport system. Estimation of road freight tone-km/year is carried out using population, gross domestic product and number of vehicles i.e. lorries using genetic algorithm (GA) approach. Based on Genetic Algorithm (GA) approach, four forms of the Freight Transport Demand Model (GAFTM) are proposed. Best fit model to historical data is selected for future estimation. The estimated road freight tone-km is transferred to railway freight. Transformations are made to obtain one equivalent value of lorry that carries how much freight and correspondingly one train. Net-tone/km for train and lorry is obtained. After that three scenarios are proposed to control road freight tone-km by transferring the 1%, 2% and 3% of the road freight to railway freight. Extra income that is obtained by diverting road freight traffic to railway is calculated. Results showed that about \$180 million dollar can be gained and 84000 lorries may be saved from road in 2025 if scenario 3 is applied.

**Keywords-** Genetic algorithm, road freight tone-km, railway freight, freight transport planning

## INTRODUCTION

Road and rail freight transport provides transport and environmental policy with some of its most intractable problems. Lorries are visually very intrusive, noisy, polluting and responsible for much of the impetus behind road building strategies. They are the most visible component of a relatively new and sophisticated production and distribution system that has evolved in a way that weakens local production and consumption links and encourages longer distance supply lines. Over time the distances over which freight moves have lengthened and the amount of dependence on distant sources and complex road freighting operations has increased. In order to understand the forces that currently mould road freight operations we have to be aware of the importance of the spatial distribution of manufacturing and the geographical location of raw material and intermediate product inputs into a final manufactured product. Such awareness can reveal the beginnings of a new strategy that will move freight transport operations in the direction of sustainable development. Reference [1] has made these processes much more transparent and revealed the opportunities provided by substituting "near" for "far" in sourcing decisions.

Freight transport strategies have to be alive to a number of influences. They must recognize the importance and growing importance over time of emissions from this sector. These emissions have well recognized negative impacts on human health and even though lorries form a relatively small part of the total number of vehicles their impact on emission inventories is disproportionately large. Freight transport strategies must recognize the commercial importance of moving goods around and satisfying the transport demands from other economic sectors. This will require careful negotiation with interested parties and careful management of all transport modes and all possibilities for local sourcing. Freight transport strategies must reflect the importance of environmental and sustainable development objectives.

Forecasts of future levels of demand in road freight transport vary enormously. European Union (EU) documentation refers to a doubling of road freight [2]. More analytical studies with a well defined time framework have produced a percentage increase in tone kilometers of road freight of up to 149 [3].

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References [3]-[4] predicted a growth of 58% in tone kilometers over the period 1990-2010. In the same period fuel consumption will rise by 23-57% even taking into account improvements in energy efficiency.

Forecasts of heavy goods vehicle traffic in Great Britain [5] are based on a constant relationship between GDP and road tone kilometers. The forecast of vehicle kilometers (all heavy goods vehicles) for the period 1988-2025 is for a low growth rate of 67% and a high growth rate of 141%. Forecasting is a very inexact science and past forecasts have underestimated the size of the growth in both passenger kilometers and tone kilometers. Current transport policies are discriminating against rail, coastal shipping and waterways. There is no such thing as a level playing field and the mythology of a free market in transport could not be further from the truth. There is no market mechanism guiding the flow of funds into road building programmes.

Freight transport modelling and planning prevents traffic congestion in rural roads and reduces the resource allocation for building new highway network and improved safety. In order to make a good decision making for future prospects of road and rail freight transport, demand for freight in both highways and railways needs to be estimated with mathematical methods. One of the new methods, Genetic Algorithms (GA), first developed by [6]-[7] proposed in this study. It is a quite new method to estimate demand for freight in rural roads. Based on Genetic Algorithm (GA) approach, Freight Transport Demand Models (GAFTM) are developed that use the population, the Gross Domestic Product (GDP) and the Number of Vehicles (NoV) as inputs. One of the main reasons for choosing the GA approach is that the socio-economic and transport related indicators may affect the freight demand in non-linear behaviour.

## MODEL DEVELOPMENT

The GAFTM models use the GA notion that has been developed by [6]. Reference [7] applied its notion to the engineering problems. It is an iterative process that involves *reproduction*, *crossover* and *mutation*. The main advantage of GAs is their ability to use accumulating information about initially unknown search space in order to bias subsequent searches into useful subspaces. GAs differ from conventional nonlinear optimization techniques in that they search by maintaining a population (or data base) of solutions from which better solutions are created rather than making incremental changes to a single solution to the problem. Definition of the GA and its application to transport demand modelling may be obtained in [8]-[10].

The four forms of the GAFTM models are developed in the following way.

Exponential form of the  $GAFTM_{exp}$  model is:

$$GAFTM_{exp} = w_1 + w_2 X_1^{w_3} + w_4 X_2^{w_5} + w_6 X_3^{w_7} \quad (1)$$

Quadratic forms of the  $GAFTM_{quad}$  models are:

$$GAFTM_{quad0} = w_1 + w_2 X_1 + w_3 X_2 + w_4 X_3 + w_5 X_1 X_2 + w_6 X_1 X_3 + w_7 X_2 X_3 + w_8 X_1 X_2 X_3 \quad (2)$$

$$GAFTM_{quad1} = w_1 + w_2 X_1^{w_3} + w_4 X_2^{w_5} + w_6 X_3^{w_7} + w_8 X_1 X_2 + w_9 X_1 X_3 + w_{10} X_2 X_3 + w_{11} X_1 X_2 X_3 \quad (3)$$

$$GAFTM_{quad2} = w_1 + (w_2 X_1 + w_3 X_2 + w_4 X_3)^{w_5} \quad (4)$$

where  $X_1$  is the population ( $10^6$ ),  $X_2$  is the GDP ( $10^9$ \$) and  $X_3$  is the NoV ( $10^5$ ).

After applying the GAFTM models to estimate road freight transport using data on Table 1, the following weighting parameters are obtained.

$$GAFTM_{exp} = 0.77 + 0.26 X_1^{0.44} + 0.00 X_2 + 0.31 X_3^{1.35} \quad R^2 = 0.92 \quad (5)$$

$$GAFTM_{quad0} = 0.978 + 0.00 X_1 + 0.00 X_2 + 0.392 X_3 + 0 X_1 X_2 + 0.016 X_1 X_3 + 0 X_2 X_3 + 0 X_1 X_2 X_3 \quad R^2 = 0.91 \quad (6)$$

$$GAFTM_{quad1} = 0 + 9.041 X_1^{0.001} + 0.00 X_2 + 0.0 X_3 + 0 X_1 X_2 + 0.0189 X_1 X_3 + 0 X_2 X_3 + 0 X_1 X_2 X_3 \quad R^2 = 0.91 \quad (7)$$

$$GAFTM_{quad2} = 4.88 + (-1.47 X_1 - 0.16 X_2 + 3.34 X_3)^{0.98} \quad R^2 = 0.91 \quad (8)$$

The validation of the four forms of the GAFTM models may be obtained in [8]. Tests were carried out based on the minimum relative error in testing period. The minimum error obtained in  $GAFTM_{exp}$  model, thus it is selected for future freight transport demand estimation.

TABLE 1  
Used data for road freight demand estimation

Years	Population ( $10^6$ )	GDP( $10^9$ \$)	Goods transport	
			NoV( $10^5$ )	tone-km ( $10^9$ )
	$X_1$	$X_2$	$X_3$	$GAFTM$
1980	44.74	69.75	33.07	37.51
1981	45.86	72.78	34.46	39.01
1982	47.00	65.94	35.95	40.57
1983	48.18	62.19	37.67	42.19
1984	49.38	60.76	39.58	43.88
1985	50.66	68.20	41.80	45.63
1986	51.78	76.46	44.19	54.02
1987	52.92	87.73	45.94	58.83
1988	54.08	90.97	47.49	65.46
1989	55.27	108.68	49.00	68.24
1990	56.47	152.39	52.08	65.71
1991	57.50	152.35	55.43	61.97
1992	58.55	160.75	59.53	67.70
1993	59.61	181.99	65.98	97.84
1994	60.70	131.14	68.82	95.02
1995	61.81	171.98	71.92	112.52
1996	62.93	184.72	77.61	123.67
1997	64.08	194.36	88.34	124.34
1998	65.24	205.98	99.72	135.27
1999	66.43	187.66	107.19	134.41
2000	67.64	201.48	118.87	141.82
2001	68.59	144.00	122.97	151.42
2002	69.82	181.00	127.44	150.91
2003	69.93	238.53	137.85	152.16
2004	70.85	301.53	190.73	156.85
2005	71.76	359.97	215.20	166.83
2006	72.67	380.62	240.52	177.40

Sources: General Directorate of Turkish Highways [11], State Planning Organization [12]

## ROAD FREIGHT TRANSPORT DEMAND IN FUTURE

When road and railway freights are analyzed, the road freight is increased about 4 times, but railway freight is not considerably changed within last 21 years for the period of 1985-2006. These trends will continue if efficient freight plan is not made. Figure 1 shows the general trend of road and railway freight between 1985 and 2006 indexed at 1985 as 1. Road freight transport demand is forecasted under different scenarios using these values in this study.

Estimation of road tone-km is carried out after forecasting the socio-economic and transport related indicators. The estimation of population, GDP and NoV is carried out in the following way.

1. Population: State Planning Organization (SPO) [12] plans and controls the population growth rate in Turkey according to the 5 years National Development Plans (NDP). This plans show that the growth rate of population is separated into two categories. One is the real growth and the second is the targeted growth rate. It indicates that the population growth rate increase with a decreasing trend especially within last 15 years. Therefore, it may be better to estimate the population of Turkey in 2025 according to the two-case: One is the current population growth rate that can be obtained from

the observations and it is named as Case I, and the second is the targeted growth rate according to the NDP named as Case II.

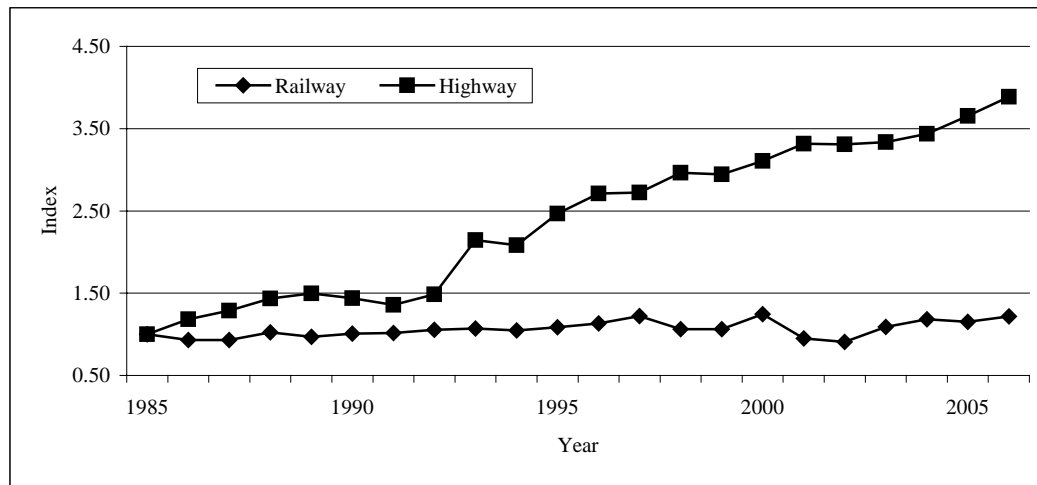


FIGURE 1

The trend of road and railway freights for the period of 1985-2006 (fixed at 1985=1) [11]-[13]

2. GDP: The observed GDP is in the fluctuating trend. Therefore, it could be better to take the average growth rate of the GDP under various cases. The cases can be explained as:

Case I: Take the average growth rate of the observed period for the GDP as a future growth rate (i.e. annual average growth rate is 4% within last 20 years),

Case II: Assume that the GDP of Turkey by means of per capita will meet the EU average in 2025 (i.e. 6% annual growth rate).

The projected GDP can be obtained in [9] based on the Case I and Case II.

3. NoV: Number of light goods vehicles (LGV) and trucks show linear increase within the last 30 years. Therefore, the following linear equations are used to predict NoV in the future.

$$y = 55667x + 173990 \quad R^2 = 0.94 \quad (9)$$

$$y = 11657x + 139389 \quad R^2 = 0.99 \quad (10)$$

where y is number of lorries and x is the time series where 1985=1, 1986=2....

Projected number of vehicles (NoV) is given in Table 2. The NoV for goods transport is  $2.8 \times 10^6$  and the total NoV is  $22.5 \times 10^5$  in 2025.

TABLE 2  
Projected NoV

Years	2010	2015	2020	2025
NoV ( $10^5$ )	178.81	212.47	246.13	279.79

Expected road freight tone-km may be analyzed under four combinations as:

	<u>Population</u>	<u>GDP</u>	<u>NoV</u>
I. Combination	Case I	Case I	Table 2
II. Combination	Case I	Case II	Table 2
III. Combination	Case II	Case I	Table 2
IV. Combination	Case II	Case II	Table 2

Application of  $GAFTM_{exp}$  model for road freight tone-km under four combinations can be seen in Figure 2 for the period of 2007-2025. The lowest and highest estimated road freight tone-km is about between 530 and

$575 \cdot 10^9$  tone-km/year for combinations I and II. Therefore, combination I and II is selected for future analysis.

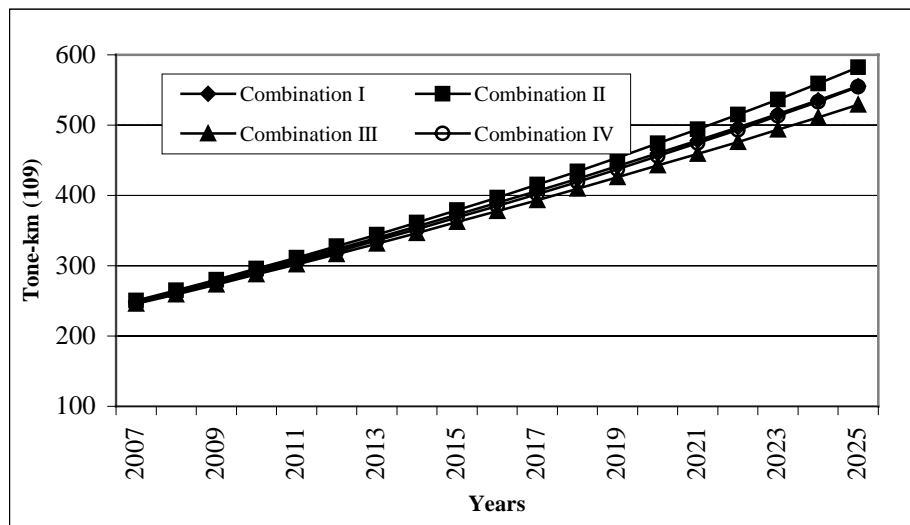


FIGURE 2  
Estimated road freight tone-km under four combinations

## SCENARIOS AND FREIGHT DEMAND ANALYSIS

The forecasted road freight transport is transferred to the railways under three scenarios. It is assumed that until 2010 there are no policy changes for all scenarios. All the analyses are carried out after 2010. If some part of the road freight is transferred to a railway, then it requires some extra time to plan its coming extra demand from road freight.

*Scenario 1:* Each year 1% of the road freight is transferred to railway and it steadily increases, meaning that 15% decrease on road tone-km in 2025.

*Scenario 2:* Each year 2% of the road freight is transferred to railway and it steadily increases, means that 30% decrease on road tone-km in 2025.

*Scenario 3:* Each year 3% of the road freight is transferred to railway meaning that and 45% decrease on road tone-km in 2025.

TABLE 3  
Transferred road freight tone-km to railway for the period of 2011 to 2025

Year	Expected road freight demand (10 <sup>6</sup> tone-km)	Transferred road freight (10 <sup>6</sup> tone-km) to railway freight		
		Scenario 1	Scenario 2	Scenario 3
2011	303.53	3.04	6.07	9.11
2012	319.02	6.38	12.76	19.14
2013	334.92	10.05	20.10	30.14
2014	351.26	14.05	28.10	42.15
2015	368.03	18.40	36.80	55.20
2016	385.00	23.10	46.20	69.30
2017	402.41	28.17	56.34	84.51
2018	420.26	33.62	67.24	100.86
2019	438.57	39.47	78.94	118.41
2020	457.33	45.73	91.47	137.20
2021	476.33	52.40	104.79	157.19
2022	495.80	59.50	118.99	178.49
2023	515.75	67.05	134.09	201.14
2024	536.19	75.07	150.13	225.20
2025	557.13	83.57	167.14	250.71

Forecasted road freight tone-km and transformations to railway freight can be seen in Table 3. As can be seen, the minimum values of  $84 \cdot 10^6$  tone-km and  $250 \cdot 10^6$  tone-km can be transported by train according to scenario 1 and 3, respectively.

After transferring the road freight tone-km to railway will lead to change the railway freight net-ton-km and it creates some extra income. Current level of railway revenues for only freight transport can be seen in Figure 3. Figure indicates that there is a floating trend in observed revenues between 1985 and 2000. After 2001 observed revenues slightly increased. It is expected that increasing trend of freight income will continue in future years.

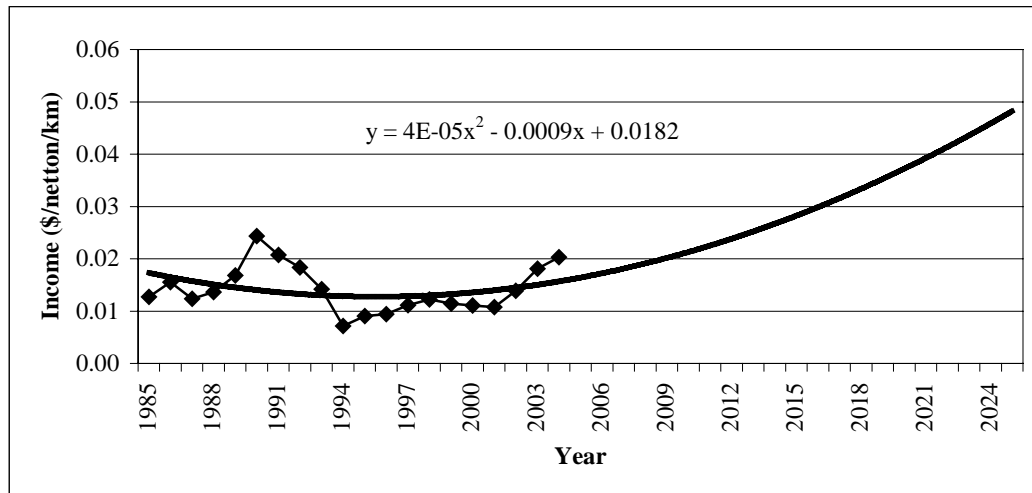


FIGURE 3

Observed and expected revenues for railway freight net-ton/km.

In order to calculate the equivalent unit value of road freight tone-km, there is a need to estimate how much the average value of one lorry that moves with a goods and similarly one train. It is obtained that one lorry carried 3 tones and one train carries 170 tones. Using these values, transformations from road freight to railway freight are made. Results can be seen in Table 4. Expected extra revenues from rail transport are about  $\$60 \cdot 10^6$  to  $\$180 \cdot 10^6$  in 2025 for scenario 1 and 3, respectively.

TABLE 4  
Divided railway freight demand and extra revenue for railways

Year	Net-tone/train-km ( $10^6$ )			Extra revenues ( $\$10^6$ ) for railways		
	Scenario 1	Scenario 2	Scenario 3	Scenario 1	Scenario 2	Scenario 3
2011	55	110	166	1.03	2.06	3.09
2012	116	232	348	2.28	4.56	6.84
2014	255	511	766	5.58	11.16	16.74
2015	335	669	1004	7.72	15.43	23.15
2016	420	840	1260	10.23	20.46	30.69
2017	512	1024	1536	13.18	26.37	39.55
2018	611	1223	1834	16.63	33.25	49.88
2019	718	1435	2153	20.63	41.25	61.88
2020	832	1663	2495	25.24	50.49	75.73
2021	953	1905	2858	30.54	61.08	91.63
2022	1082	2163	3245	36.61	73.21	109.82
2023	1219	2438	3657	43.52	87.04	130.56
2024	1365	2730	4095	51.37	102.75	154.12
2025	1519	3039	4558	60.26	120.52	180.78

## CONCLUSIONS

This study deals with estimation of road freight transport demand indicators in Turkish rural roads and analysis the railway extra revenues if some part of the road freight is transferred to railways. The GAFTM models are developed using population, GDP and number of vehicles. The road freight demand is projected with four cases under four combinations of the cases. GA approach is selected as a methodology so that road freight tone-km may be better estimated by the non-linear form of the mathematical expressions. Among the four forms of the GAFTM models, the best of the GAFTM model is selected in terms of minimum total average relative errors in testing period. The following results can be drawn from this study.

The analysis has shown that the potential for reducing the number of lorry movements in Turkey is very large and much larger than previously recognized. This reduction can be achieved in part by transferring freight from road to rail. It is clear, however that a transfer of this kind cannot represent a fundamental solution to the problems of rising ton-km of road freight. Freight transport offers a number of attractive options for building alternatives. Establishing the importance of regional and local production/consumption links and reducing the basic demand for freight transport is one of these alternatives.

The case for fundamental demand reduction in road freight transport is a strong one and the time has arrived when continuing to develop along the same path as the last 20 years is no longer acceptable and is in clear conflict with sustainable development objectives. There is a way forward and sustainable development is a stimulus to innovation and experimentation that will chart a new course.

Analysis showed that minimum of 1000 lorries discarded from road traffic according to scenario 1 in 2011 and 83570 lorry will be discarded from road traffic if scenario 3 is applied in 2025. This means that improved road safety and environmental pollution and extra revenue for railways.

## ACKNOWLEDGEMENT

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# **Chapter 10**

Transport Modeling



## INVERSE MODEL TO ESTIMATE O-D MATRIX FROM LINK TRAFFIC COUNTS USING ANT COLONY OPTIMIZATION

Halim CEYLAN<sup>1</sup>   Soner HALDENBİLEN<sup>2</sup>   Hüseyin CEYLAN<sup>3</sup>   Özgür BASKAN<sup>4</sup>

**Abstract-** Estimation of Origin–Destination (O-D) trip table has long been carried out with maximum entropy, generalized least squares, bi-level programming methods etc. All optimization models developed so far are either calculus based and mathematically lengthy. All approaches are prone to local optima. Therefore, there is a need for a new method which estimates O-D trip table and solves the traffic assignment models simultaneously. The main objective of this study is therefore to develop a model to estimate O-D trip table from link traffic counts using ant colony optimization (ACO) method based on inverse modelling technique. The ACO has been recently developed, as a population based meta-heuristic that has been successfully applied to several NP-hard combinatorial optimization problems. The core of ant's behavior is the communication between the ants by means of chemical pheromone trails, which enables them to find shortest paths between their nest and food sources. Ant Colony optimization O-D Estimation (ACODE) model is formulated as simultaneous optimization problem, the O-D trip matrices and stochastic user equilibrium (SUE) path and link flows are obtained simultaneously. The ACODE model is applied to an example transportation network which has 13 nodes with 19 links, 25 routes and 4 O-D pairs. O-D trip table is estimated using proposed ACODE model from given link traffic volumes. Results showed that inversely applied ACODE model for O-D matrix estimation from link traffic counts may estimate the O-D trips under SUE assumption.

**Keywords-** O-D estimation, link traffic counts, ant colony optimization, stochastic user equilibrium

### INTRODUCTION

The Origin–Destination (O–D) trip table estimation is an essential element of network based traffic models. Estimating O-D matrix from traffic counts on road links is of considerable importance. The O-D is also an essential ingredient in a wide variety of travel analysis and planning studies [1]. Over the past several decades, a considerable number of methods for O-D estimation have been reported in the literature. O-D matrix is the basic data for the traffic planning and management. It is a demand for traffic that flows from origins to destinations, which is expressed as a matrix to explore the movement of space flow. Statistical techniques have become popular in the estimation or updating of O-D matrix from traffic counts. The traditional way of estimating O-D from home-interview survey data is expensive [2]. Hence, generally, the estimates are based on small sample of home-interview data and thus the accuracy of the estimates suffers. This led the researchers to estimate the O-D from a variety of other data sources among which O-D estimation from link traffic counts has attracted lot of interest as the required data collection is simple and routine. The O-D demand matrix estimation methods in the literature and its advantages and disadvantages are given in the next section.

This paper is structured as follows. The next section reviews the O-D estimation matrix estimation methods. An improved ant colony optimization method and its solution procedure are proposed in Section 3. The algorithm defined to estimate the O-D matrix using improved ant colony optimization with inverse model from the link traffic counts is given in Section 4. In Section 5, a numerical example is carried out to present effectiveness for proposed algorithm. Finally, our conclusions can be seen in the last section.

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## LITERATURE REVIEW

O-D matrix estimation has been studied by a few researchers and notable developments have been achieved at this concept of transportation network design. Reference [3]-[5] were interested in finding probable O-D movements in terms of link flows by deterministic assignment equation. Reference [6] was the first to attempt the equilibrium assignment based O-D estimation. The formulation, however, does not ensure a unique O-D solution because the formulation is not strictly convex in the O-D variables. Uniqueness of the solution is ensured if a target O-D is used [7]-[9]. These models require a complete set of link counts, a target O-D matrix and that the observed flows be in equilibrium.

Two significant methods which do not use entropy formulation and include generalized least squares estimation were developed by [10] and [11]. Reference [2] developed another method which also uses generalized least squares and also allows the explicit use of data describing the structure of the O-D. Reference [12] proposes a model which inferences about an O-D matrix from a single observation on a set of link flows. Two problems are discussed in this study; the first, the problem of reconstructing the actual number of O-D trips, and the second, estimation of mean O-D trip rates. A fast constrained recursive identification (CRI) algorithm is proposed to estimate O-D matrices by [13]. The basic idea of the CRI algorithm is to estimate intersection O-D matrices based on equality-constrained optimization. A Fuzzy inference based assignment algorithm to estimate O-D matrices from link volume counts is proposed by [1].

Reference [14] proposes a new model which has been formulated by using a new approach called the calibration and demand adjustment model (CDAM) based on bi-level programming which simultaneously estimates an O-D matrix and the parameters for the nested logit model. The algorithm iterates between the network equilibrium problem and that which is used to obtain a set of paths when equilibrium is attained, and the CDAM is restricted to the set of previously generated columns. The computational tests on the algorithm have been carried out using data from a multi-modal network in Madrid.

In this study, an improved ant colony optimization (IACO) based algorithm which is called ACODE is proposed to estimate O-D demands on transportation networks. The ACODE model considers Stochastic User Equilibrium (SUE) conditions for modeling drivers' route choice perceptions. The methodology is given in the next sections and the model is applied to a test network.

## ANT COLONY OPTIMIZATION

Ant Colony Optimization (ACO) belongs to the class of biologically inspired heuristics. The ACO is the one of the most recent techniques for approximate optimization methods, was initiated by [15]. The core of ant's behavior is the communication between the ants by means of chemical *pheromone* trails, which enables them to find shortest paths between their nest and food sources. The Improved algorithm for ACO (IACO) that is proposed in this study is based on each ant searches only around the best solution of the previous iteration with coefficient  $\beta$ . It is very important for improving IACO's solution performance. IACO differs from other ACOs in that its feasible search space (FSS) is reduced with coefficient  $\beta$  and its best solution obtained using information on the previous iteration. At the core of IACO, ants search randomly the solution within the FSS to reach optimum or near-optimum values. At the end of the each iteration, only one of the ants is near to global minimum. After the first iteration, when global minimum is searched around the best solution of the previous iteration using  $\beta$ , the IACO will quickly reach to the global minimum. IACO is performed by modifying the algorithm proposed by [16]. The algorithm can be defined in the following way.

At the beginning of the first iteration, all ants search randomly best solution of the problem within the FSS. At the end of the first iteration, FSS is reduced by  $\beta$  and best solution obtained of the previous iteration is kept. Optimum solution is then searched in the reduced search space during the steps of algorithm progress. IACO reaches to the global minimum as ants find their routes in the limited space.  $\beta$  guides the bounds of search space throughout the IACO application. The main idea of proposed algorithm is given in Figure 1. Main advantageous of IACO is that the FSS is reduced with coefficient  $\beta$  and it uses the information taken from previous iteration. For example, consider a problem of five ants represents the formulation of the problem. Five ants being associated five random initial vectors. Only one of the solutions which were obtained at the end of the first iteration is near to

global minimum. After the first iteration, FSS is reduced according to coefficient  $\beta$  and best solution (Ant 1 is the best solution, as shown in Fig. 1(a)) of the previous iteration. FSS is getting smaller during iteration progress as shown in Fig. 1(b). Coefficient  $\beta$  has been chosen according to the size of search space and constraints the problem in order not being trapped in bad local minimum. In IACO, let number of  $m$  ants being associated with  $m$  random initial vectors ( $x^k$  ( $k = 1, 2, 3, \dots, m$ )). Quantity of pheromone ( $\tau_i$ ) only intensifies around the best objective function value. The solution vector of the each ant is updated using (1).

$$x_t^{k(new)} = x_t^{k(old)} \pm \alpha \quad (t = 1, 2, \dots, I) \quad (1)$$

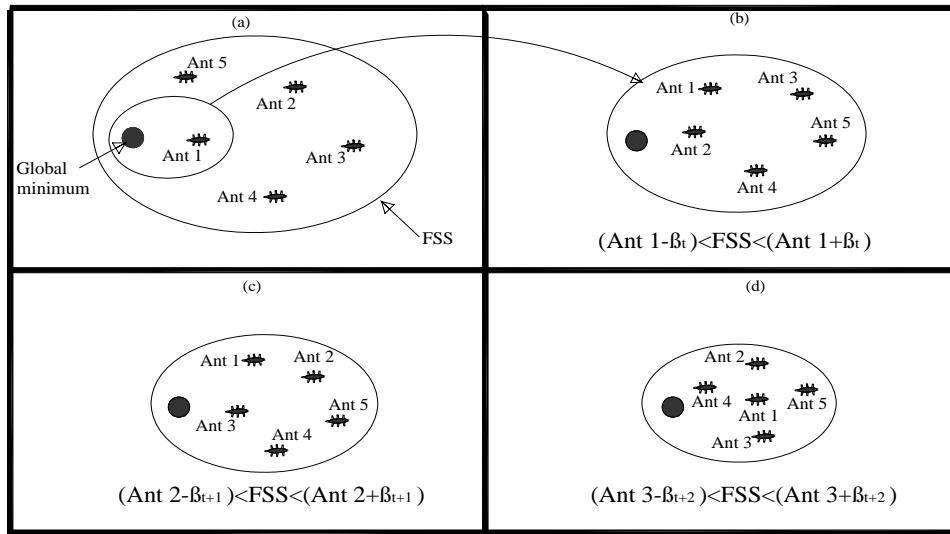


FIGURE 1

Main idea of IACO model (FSS is getting smaller during the optimization process using previous information and coefficient  $\beta$ )

where  $x_t^{k(new)}$  is the solution vector of the  $k^{\text{th}}$  ant at iteration  $t$  (see Figure 2),  $x_t^{k(old)}$  is the solution obtained from the previous step at iteration  $t$ , and  $\alpha$  is a vector generated randomly to determine the length of jump.

Ant vector  $x_t^{k(new)}$  obtained at  $t^{\text{th}}$  iteration in (1) is determined using the value of same ant obtained from previous step. At the last step of the each iteration, a new ant colony (see Figure 2, second loop) is developed as the number of colony size that is generated at the beginning of the each iteration. Steps of algorithm are illustrated in Figure 2. Quantity of pheromone ( $\tau_i$ ) is reduced to simulate the evaporation process of real ant colonies using (2). After reducing the number of pheromone, it is updated using (3). This process is repeated until the given number of iteration,  $I$ , is completed.

$$\tau_t = 0.1 * \tau_{t-1} \quad (2)$$

$$\tau_t = \tau_{t-1} + 0.01 * f(x_{t-1}^{best}) \quad (3)$$

In Equation (1), (+) sign is used when point  $x_t^k$  is on the left of global minimum on the  $x$  coordinate axis. (-) sign is used when point  $x_t^k$  is on the right of global minimum on the same axis. The direction of movement is defined by (4).

$$\bar{x}_t^{best} = x_t^{best} + (x_t^{best} * 0.01) \quad (4)$$

If  $f(\bar{x}_t^{best}) \leq f(x_t^{best})$ , (+) sign is used in (1). Otherwise, (-) sign is used. ( $\pm$ ) sign defines the search direction of movement to reach to the global minimum.  $\alpha$  value is used to define the length of jump, and it will be gradually decreased in order not to pass over global minimum, as shown in Figure 2.

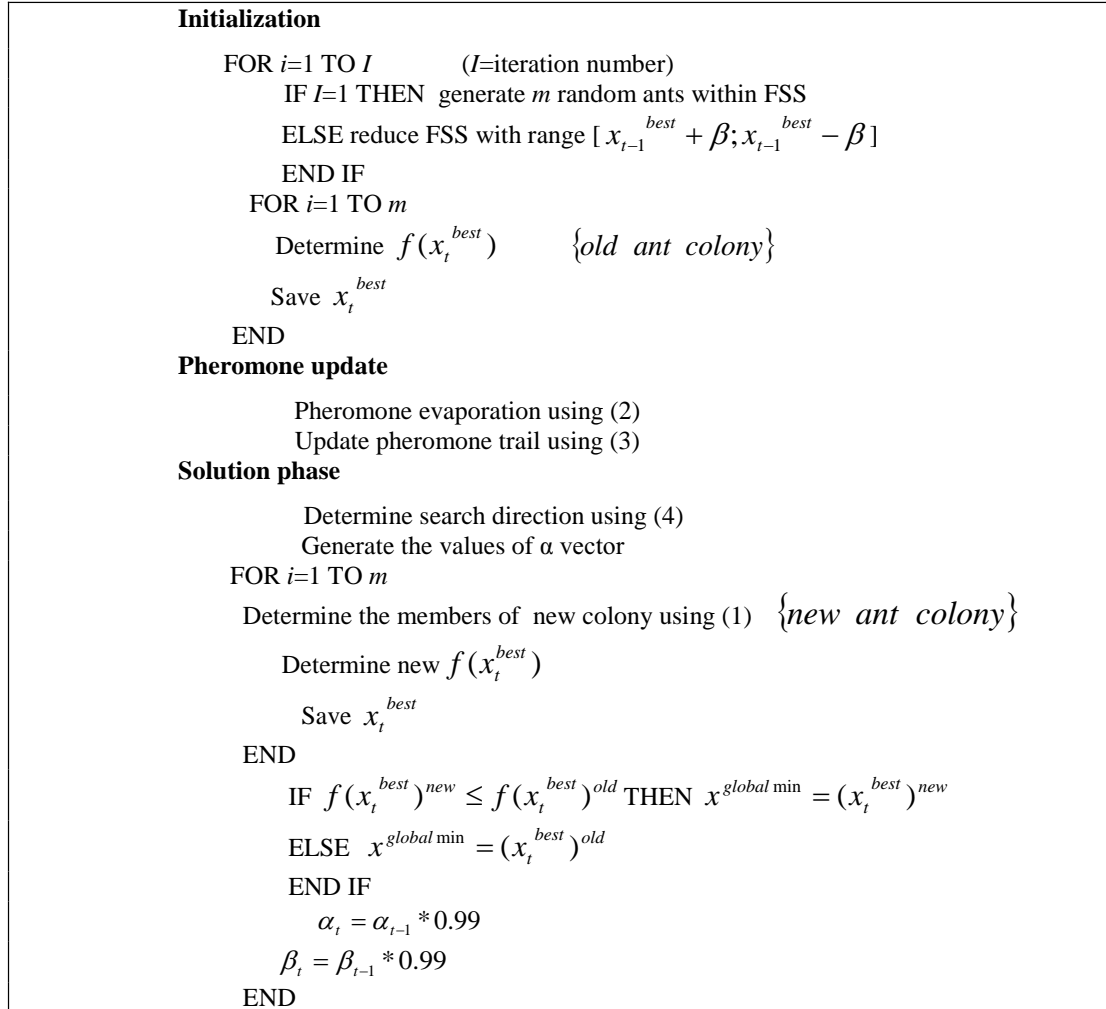


FIGURE 2  
Steps of IACO

The IACO is performed by means of reduced search space with  $\beta$  and using the information provided by previous solution. Moreover, IACO differs in terms of the generated new colony. Means that at the last step of the each iteration, a new colony is developed as a number of colony size, that is generated at the beginning of each iteration and the length of jump is applied to the same ant of the previous step at the iteration  $t$  to generate a new colony instead of applying the best ant, which obtained from previous iteration.

## PROPOSED O-D MATRIX ESTIMATION TECHNIQUE

ACODE is SUE based method that considers perceived route travel times of drivers by using C-Logit route choice model [17]. SUE assignment can be expressed as a fixed-point problem in the link flow space, over the non-empty, compact and convex set of feasible link flow patterns by following the works by [18]-[19]. The fixed problem can be written as

$$v_a = \sum_{w \in W} \sum_{r \in R_w} q_w \delta_{ar}^w p_r^w(\mathbf{t}^w), a \in L \quad (5)$$

where  $v_a$  is the link traffic volume on link  $a$ ,  $a \in L$ ,  $q_w$  is the travel demand between the O-D pair  $w \in W$ ,  $\delta_{ar}^w$  is the link-path incidence matrix where  $\delta_{ar}^w = 1$  if route  $r$  between O-D pair  $w$  uses link  $a$  and 0 otherwise,  $p_r^w(\mathbf{t}^w)$  is the probability of drivers choosing route  $r \in R$  and  $\mathbf{t}^w$  is a vector of travel times of all routes between the O-D pair  $w$ .

C-Logit model is adopted for the numerical calculation section of this study since application is quite easy. The probability of choosing route  $r$  may be expressed with C-Logit model is given in (6).

$$p_r^w(\mathbf{t}^w) = \frac{\exp(-\theta_0 t_r^w - \theta_1 CF_r^w)}{\sum_{k \in R_w} \exp(-\theta_0 t_k^w - \theta_1 CF_k^w)}, r \in R_w, w \in W \quad (6)$$

where  $CF_r^w$  is the commonality factor for route  $r \in R_w$  and it represents the degree of similarity of route  $r$  with the other routes in the set of  $R_w$  between the O-D pair  $w \in W$  and  $\theta_0 - \theta_1$  are the parameter of the Gumble random variable, directly proportional to the standard error of perceived path costs. Several ways are suggested to specify the commonality factor that gives similar results with each other by Cascetta *et al.* (1996). The commonality factor used in this study is given in (7) as

$$CF_r^w = \sum_{a \in A} \delta_{ar}^w w_{ar}^w \ln N_a^w, r \in R_w, w \in W \quad (7)$$

where  $N_a^w$  is the number of routes, connecting O-D pair  $w \in W$  that share link  $a$  and  $w_{ar}^w$  is the proportional weight of link  $a$  for route  $r \in R_w$ , specified as the fraction of total route travel time which is attributed to link  $a$ :

$$w_{ar}^w = \frac{t_a}{t_r^w} \quad (8)$$

where  $t_a$  is the link travel time and  $t_r^w$  is the corresponding route travel time.

SUE assignment part ends after finding route choice probabilities and new link flows ( $v_a^*$ ) can be obtained by using (5) with respect to randomly generated O-D trips. Minimization of the following objective function provides requested O-D demands.

$$\min F(v_a, v_a^*) = \sum_{a \in L} (v_a - v_a^*)^2 \quad (9)$$

where,  $v_a$  is observed and  $v_a^*$  is obtained link flows from estimated O-D movements. A flowchart for the ACODE model is given in Figure 3.

## APPLICATION OF PROPOSED METHOD TO ESTIMATE O-D TRIP TABLE

Let us now consider the application of the method described in the previous section. By way of illustration, consider the figure of network given in Figure 4, where the equilibrium path flows are generated randomly. This network is also studied by [20] in order to estimate origin destination matrices in congested traffic networks using column generation algorithm.

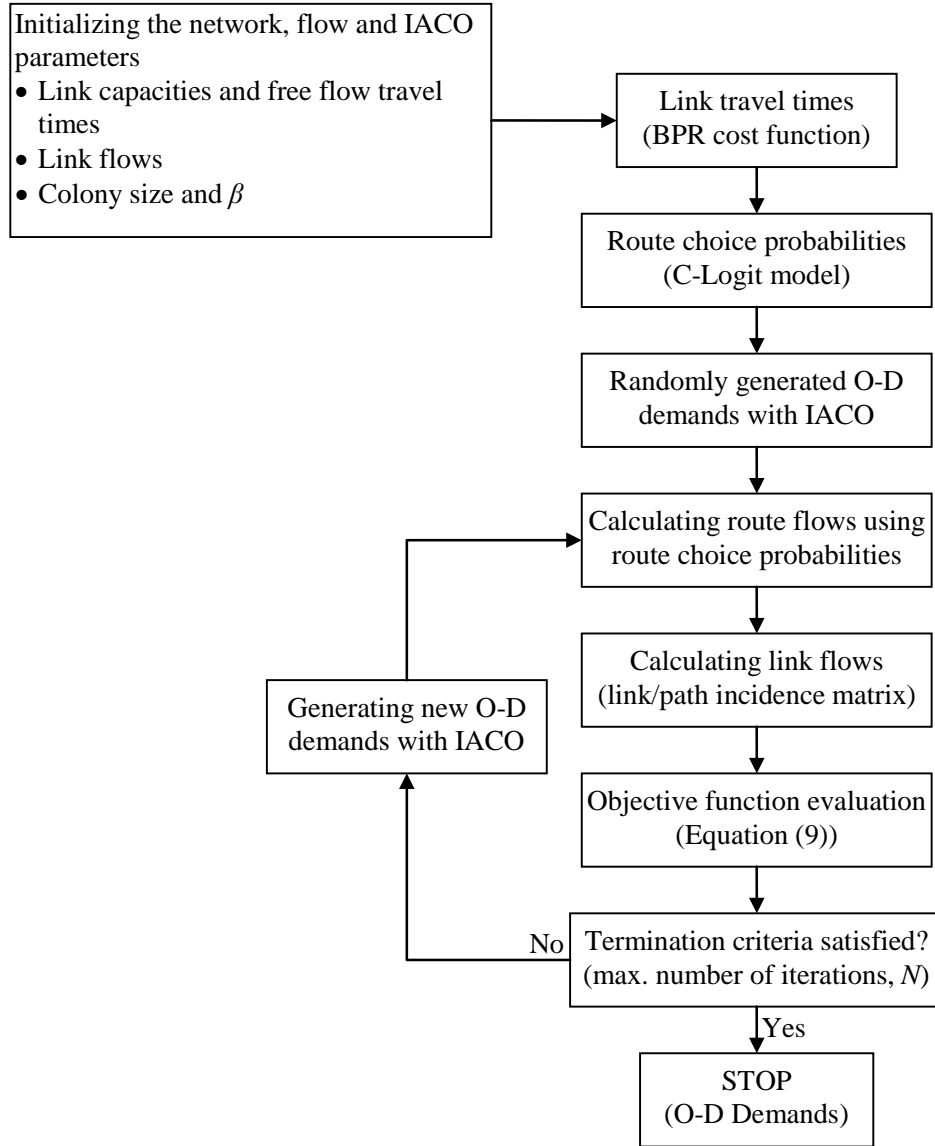


FIGURE 3  
The solution algorithm of ACODE model

The standard Bureau of Public Roads (BPR) function which is given in (10) adopted with  $b_a=1$  ve  $n_a=2$ ,  $\forall a \in L$  in order to find link costs. The other parameters of the BPR function are given in Table 2.

$$T_a(V_a) = t_a^0 \left[ 1 + b_a \left( \frac{V_a}{C_a} \right)^{n_a} \right] \quad (10)$$



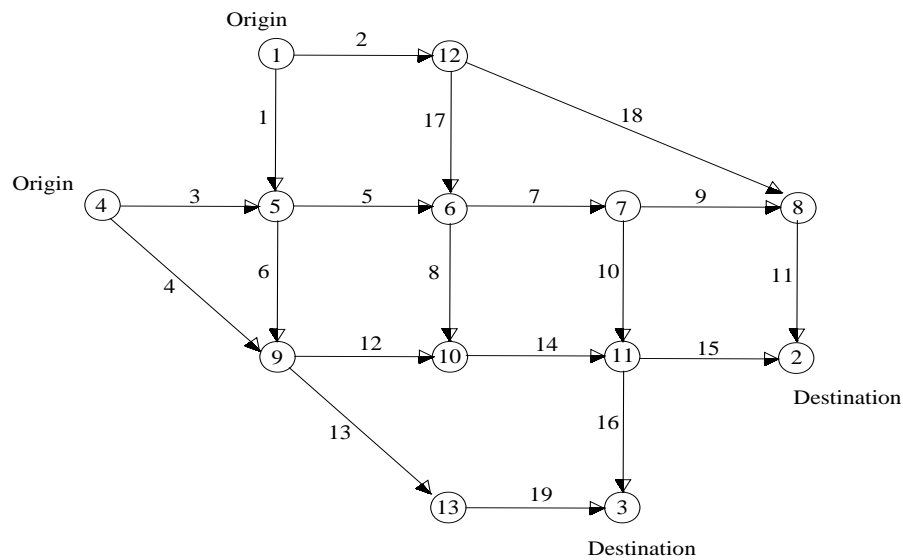


FIGURE 4  
Test network ([21])

As shown in Figure 4, test network has 13 nodes with 19 links and 25 routes between 4 O-D pairs which are given in Table 1.

TABLE 1  
Test network topology and equilibrium path flows

O-D movement	O-D pair	Path	Link sequence	Path flows	O-D movement	O-D pair	Path	Link sequence	Path flows
1	(1,2)	1	2-18-11	276	3	(1,3)	14	1-6-13-19	230
		2	1-5-7-9-11	112			15	1-5-7-10-16	107
		3	1-5-7-10-15	83			16	1-5-8-14-16	90
		4	1-5-8-14-15	76			17	1-6-12-14-16	105
		5	1-6-12-14-15	98			18	2-17-7-10-16	146
		6	2-17-7-9-11	145			19	2-17-8-14-16	123
		7	2-17-7-10-15	113			20	4-13-19	295
		8	2-17-8-14-15	98			21	4-12-14-16	157
2	(4,2)	9	4-12-14-15	386	4	(4,3)	22	3-6-13-19	201
		10	3-5-7-9-11	378			23	3-5-7-10-16	133
		11	3-5-7-10-15	261			24	3-5-8-14-16	105
		12	3-5-8-14-15	222			25	3-6-12-14-16	109
		13	3-6-12-14-15	254					

TABLE 2  
Link cost parameters

Link	Free flow travel time, $t_a^0$	Link capacity, $C_a$
1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16, 17, 19	10	2000
4	20	2000
13	20	2000
18	30	2000

In order to show the effectiveness of the ACODE, the evaluation of objective function during the iteration process is given in Figure 5. As can be seen in Figure, ACODE achieved to exact solution for given objective function about after 500 iterations.

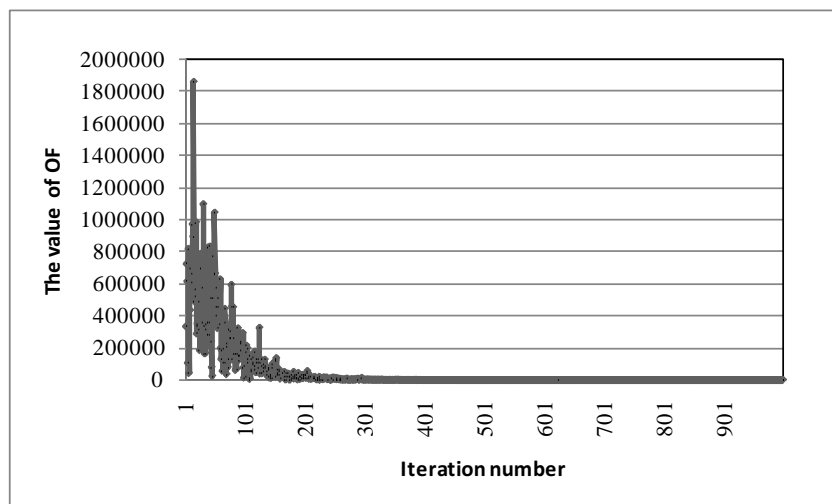


FIGURE 5  
The evaluation of objective function (OF)

O-D demand matrix is obtained using ACODE model after 1000 iterations and given in Table 3.

TABLE 3		
Obtained O-D trip table using ACODE model		
Origin	Destination	
	2	3
1	1000	800
4	1500	1000

## CONCLUSIONS

This paper deals with the development of a new algorithm to estimate O–D matrices from observed link traffic counts. A new approach called ACODE has been formulated based on SUE conditions. We have proved the existence of solutions for ACODE. Test network which has 13 nodes, 19 links, 25 routes and 4 O-D pairs is used to show the effectiveness of ACODE algorithm. Numerical results showed that the proposed ACODE algorithm is able to estimate O-D trip table from link traffic counts. Further, the results show that the proposed approach holds promise for successful application to large networks with complex flow patterns.

## ACKNOWLEDGEMENT

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# THE IMPACT OF LOGISTICS ON MODELLING COMMERCIAL FREIGHT TRAFFIC

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**Abstract** — Commercial traffic includes all shipments of goods and passengers in conjunction with commercial and business related activities. For the last decades the freight conveyance in Europe increased remarkably and further growth is forecasted. The main reasons for this development are globalisation, the EU eastward enlargement, innovations in information and communication technology as well as changes in sourcing, production and delivery concepts of supply chains. Depending on these changes freight transport models should be adapted but they are often just based on general, aggregated data. To improve the basis for modelling transport operations, the knowledge about logistics in production networks and supply chains has to be enlarged. Hence, a research project analysing the relationship between commodity flows and transport flows has been established.

*Commercial freight traffic, commodity flows, logistics, transport modelling*

## INTRODUCTION

During the last decades logistics gained importance and became a significant part of companies' acting. This development is especially influenced by political and economical changes as well as technological innovations. Political changes contain for example the deregulation of the transport market and the telecommunication market. Additionally the EU eastward enlargement as a politically driven development has impact on production locations and commercial relationships [1]. Besides, after the introduction of the Euro trade was even more simplified and prices easier to compare. Technological innovations concerning logistics comprise especially information and communication technology. The increasing use of the e-commerce determines more direct shipments to customers and actually the internet provides global integrated logistics networks. Finally the economic growth and global trade causes more international transports and thus requires special logistics.

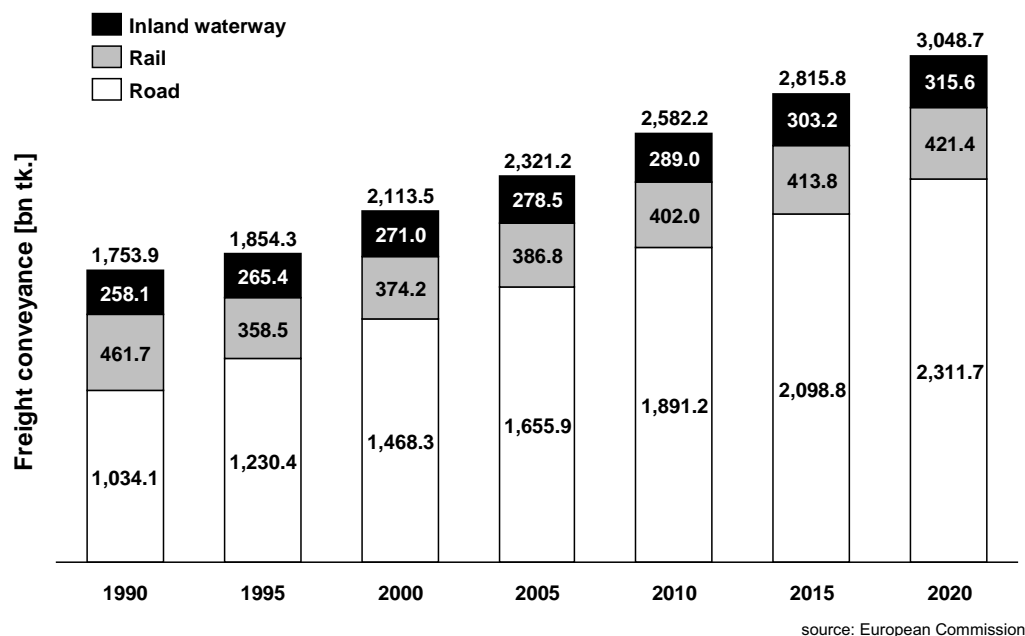


FIGURE. 1  
Development of freight conveyance in the EU-25.

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In conjunction with these developments the commercial traffic in Europe increases continuously. Especially the freight conveyance is characterised by a remarkable growth of nearly 40 % from 2005 to 2020 (see Figure. 1). At the same time the volume of transport will decrease. Thus, commodities are shipped for longer distances. Besides, in all European countries road transport is the most common used transport mode. About 75 % of the total freight conveyance in the EU countries is shipped by lorry [2]. Road transport is the most flexible one and therefore it can be assumed that time definite and flexible logistics concepts amplify the use of this transport mode. Nevertheless, although there exist several characteristics which indicate a relationship between logistics and traffic growth the knowledge, especially regarding transport modelling, is still insufficient.

## LOGISTICAL TRENDS

Currently a multiplicity of logistics concepts and strategies exists in different corporate divisions of firms. The main objective of these concepts is to optimize processes (intra-corporate and inter-corporate ones) and finally to reduce costs. The literature review indicates the existence of general logistics trends that can be identified in production industry as well as in trading. They contain especially sourcing, consolidation and delivery aspects.

A major trend is the globalisation which is not exclusively a logistics trend but rather a driver of several trends. Due to the globalisation regional sourcing is increasingly replaced by global sourcing. Companies often purchase goods from other countries or even continents to reduce purchase prices because these suppliers are often cheaper than regional ones [3]. At the same time logistics chains become more complex. Comparatively, the distribution of finished goods is effected more globally. Besides another trend in sourcing is the so called modular sourcing. As a result of the decreasing production depth more processes are carried out by suppliers and the level of in-house production is reduced [4]. Thus, even the assembling of complex modules is outsourced. The aim of modular sourcing is to decrease the amount of relations between suppliers and recipients and to simplify the purchase process. At the same time those modules are often characterised by a relatively high volume as well as a high value and thus storing causes high costs. Therefore such modules are delivered using just in time concepts which require high logistics demands. Generally time definite delivery concepts like just in time and just in sequence are more complex than conventional delivery concepts. But due to the increasing trend to consumption-driven purchasing these concepts become more common and are applied in several branches.

TABLE 1  
Logistics shifts and possible impact on transport

Logistics shifts	Implications	Vehicle-kilometers	Shipment size
Reduction of the production depth	Lower level of in-house-production	++	o
Fewer partners / single sourcing	Reduction of the amount of suppliers	-	+
Just-In-Time-procurement	More frequent transport movements; less use of cargo room to capacity	+	-
Local sourcing	Suppliers in close proximity	-	-
Global sourcing	More complex procurement	+	+
Modular sourcing	Fewer suppliers but more responsibility	o*	o

\* depends on spatial distribution and consolidation with different suppliers

++ large increase, + small increase, o conclusion impossible, - small decrease, -- large decrease

As mentioned before another trend in delivering is the direct shipment to end customers which requires a multiplicity of parcel services. Especially the growing use of internet sale platforms provides the delivery of small shipments between end customers. The logistical restructuring also contains the spatial concentration of production and inventory. In the past production and storage were often located decentralised in several countries. Today the trend goes to centralised locations and appropriate global logistics concepts [5]. Hence,

logistics service providers (LSP) play an important role. Originally logistics processes in companies were organised by the company itself and transport processes between different company locations were normally managed by forwarders. Nowadays many logistics processes have been outsourced to LSP. In addition to 'traditional' logistical tasks they also offer supplementary services and control the complete logistics chain.

The above mentioned trends show an ongoing development in the reorganisation of companies and the associated logistical restructuring. It is obvious that this development has impact on the resulting freight traffic. Hence, some approaches exist which contain assumptions of the relation between logistics concepts and transports, but often the results just describe generalised dependencies (e.g. [6], [7], [8]).

## TRANSPORT MODELLING

Compared to passenger transportation modelling, the field of freight modelling is relatively unexplored. Many approaches are still based on the four-step modelling structure which has originally been developed for passenger transport [9]. In the first step the quantities of goods being transported from origin zones and those being transported to destination zones are determined. Secondly flows (in tonnes) between various origin and destination zones are determined. Within the third step the commodity flows are allocated to modes and finally they can be assigned to networks [9].

There exist significant differences between freight and passenger transport. In contrast to passenger transport several decision-makers are involved in the transport process (e.g. sender, receiver, shipper, forwarder, LSP). Furthermore freight transport networks consist of a multiplicity of nodes and links and therefore they are more complex. Additionally, the items being transported are more diverse and range from small parcel deliveries with multistops to single bulk shipments [9], [10].

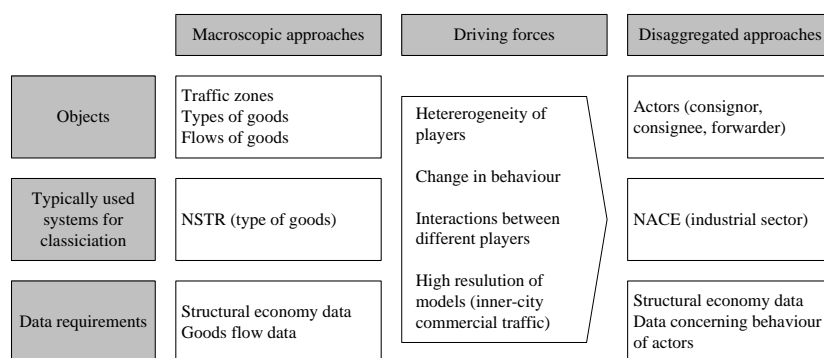


FIGURE. 2  
Development of freight transport modelling [10].

Many modelling approaches describe traffic based on aggregated figures like number of employees, type of industry and spatial distribution of industries. The growing influence of logistics networks, transport operations and production strategies is often neglected. In the past it was often presumed that transport flows pass similarly to the associated commodity flows. But due to the increasing application of logistics strategies in supply networks, transport flows are normally more complex. Generally, transport flows in production networks cannot proportionally be calculated based on the amount of pieces and components that compose the finished product. There are two main reasons for this. First of all, the number of required means of transport is calculated in fixed steps. Secondly, the multiplicity of logistics strategies in production networks causes different traffics. Accordingly, transport flows of production networks have to be examined in addition to the corresponding commodity flows. Nevertheless, commercial freight traffic models and forecasting approaches are mostly based on aggregated flows between different levels of added value. An overview of existing transport models is shown by Persson and Davidsson [11].

## ESTABLISHED APPROACH

To improve the basis for modelling transport operations, the knowledge about logistics in production networks and supply chains has to be enlarged. Hence, a research project analysing the relationship between commodity flows and transport flows has been established. In the first step a theoretical approach has been developed. The main intention to generate a theoretical approach is to create a basis for aggregating

theoretical knowledge and to prepare an empirical analysis. To deduce interrelations between logistics concepts and induced traffic, all parameters influencing transport have to be analysed. Thus, the analysis is not limited on logistics aspect but on a comprehensive examination.

In a first step existing approaches describing the relation between logistics and traffic (e.g. [6], [7], [8]) have been analysed and tested with regard to combination and extensibility. A comparison of several approaches enabled the identification of redundancies and gaps. Based on the analysis of these approaches a theoretical framework describing the system “transport” has been developed. The framework contains a multiplicity of parameters, which can be aggregated into different clusters. The analysis showed that it seems to be appropriate to define four clusters of factors that influence transport within the first level. They are named as follows:

- External factors: all factors, which exist independently of transport processes and which are normally not controllable.
- Actors: all actors being involved in the transport process.
- Commodity: all commodity relating factors that impact the transport process (physical characteristics as well as logistical characteristics).
- Means of transport: all factors relating to the means of transport and which influence the transport depending on the chosen decision.

The parameters are divided in further sub-parameters in the complete framework.

The next step contained an analysis whether the four clusters can be prioritised. It has been deduced that dependencies between these clusters exist and thus a ranking has been established. The method of the pairwise comparison shows that the “External factors” constitute the first rank because they influence the other clusters significantly. The “Actors” behave as autonomic individuals and therefore they are positioned on the second rank. Finally, comparing the two clusters “Means of transport” and “Commodity” shows a prioritisation of the latter one because the characteristics of the object being transported have impact on the means of transport.

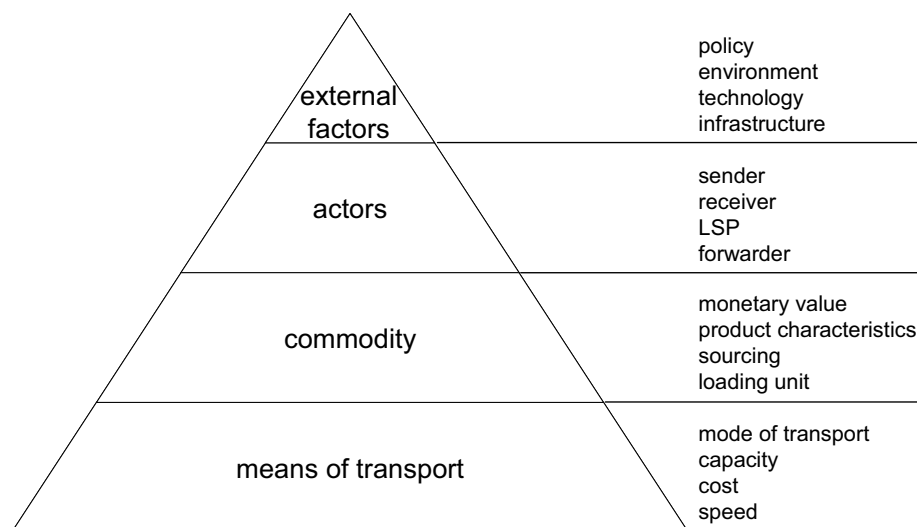


FIGURE. 3  
Parameters influencing freight transport.

A pyramid (see Figure. 3) which arranges the four clusters hierarchically has been developed for visualising the ranking. The enumerations on the right hand side of the pyramid show exemplary sub-parameters which have been aggregated within the relative cluster. Due to the chosen arrangement not all sub-parameters are presented. Noticeably, the last three clusters include many logistical aspects. This underlines the important impact that logistics have on the resulting traffics.

The collected parameters describe a basis for the ongoing research. In the next step the developed framework with its parameters will be implemented in an empirical analysis to deduce cause-effect relations between commodity flows, logistics strategies and induced transports. A special focus is on the commodity specific characteristics and their influence on the resulting transport relations. It is assumed that dependencies



between the shipped commodities and applied logistics strategies exist. Based on a top-down network analysis of one specific product the transport chain will be analysed.

That means in a first step to identify the suppliers of the OEM and describe their transport relation by using parameters of the theoretical framework. Analogously the relation between these suppliers and their sub-suppliers will be analysed. With some logistical background it is obvious that two suppliers of two different levels of added value are not obligatorily connected directly. Depending on the delivery concept, shipments can be transported via transshipment points or directly combined with other shipments. Hence, many types of different transport operations result. By comparing the relations between several suppliers, general dependencies and interrelations between shipped commodities and transport operations will be identified. Finally the aim is to ascertain regularities which can be used in commercial freight traffic models.

## CONCLUSION AND OUTLOOK

This paper has presented ongoing trends in logistics and the missing implementation of logistical aspects in freight transport models. Additionally, a research project at the Chair of Transportation Systems and Logistics, Dortmund University of Technology with focus on analysing transports in logistical chains has been introduced.

The main objective of the presented project is to identify correlations between logistics aspects referring to companies and commercial freight traffic. Based on these results, logistics aspects should be implemented in commercial traffic models prospectively. The result of the research will not constitute a real transport model but the new knowledge about the relation between logistics and traffic will improve new modelling approaches.

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## A COMPARATIVE REVIEW OF SIMULATION-BASED BEHAVIOR MODELING FOR TRAVEL DEMAND GENERATION

*Seda Yanık<sup>1</sup>, Mehmet Tanyaş<sup>2</sup>*

**Abstract** – Travel behavior modeling is a key practice in transportation planning and network performance evaluation. Until now, many analytical models were built on different theoretical bases with aggregate and static representation. However travel behavior which is derived from daily human activities has many underlying factors such as socioeconomic covariates between individuals, household decision making, activity scheduling with prioritization between obligatory and discretionary activities, as well as spatial and time related constraints. Recently, simulation-based techniques are commonly used in order to achieve to incorporate these factors with disaggregate and dynamic representation of micro-units such as individuals. Compared to aggregate techniques, microsimulations offer to maintain the heterogeneity of information and minimize the modeling bias. In this paper, underlying concepts, models and tools of the microsimulations of travel behavior will be presented with a study of literature.

**Keywords** – Activity-based approach, Customer behavior modeling, Microsimulations, Travel demand estimation

### INTRODUCTION

The aim of this paper is to compare the simulation-based systems of customer behavior modeling and their connection to travel demand estimation. Basically, travel is an output of the need for changing locations at which the traveler performs different activities. Travel demand occurs in a spatial environment mostly represented by a network so modeling is related to nodes, links and the travelers in it. In this framework, the aim of customer behavior modeling is to capture the heterogeneity of the travelers, model their choices and patronization under spatial and time related constraints incorporating the interaction between demand and supply.

For an airline trying to control the availability of fare products in order to maximize the expected revenue or a railway transportation system trying to even out the demand to maximize the performance of the network or an urban traffic planning and controlling system trying to minimize the traffic congestion, demand estimation is one of the key elements of high performance and success in the activities. For this aim, the effort to predict the demand has been put forth ever since. However recently thinking of customers as the unit of demand and understanding the underlying factors of customer behavior have become more important. In this perspective, there is a growing body of research about simulation-based demand estimation systems. The first step for demand estimation is to model the choice decision of a customer at a particular instant in time (ex. mode choice, time shifting). The main body of research about choice decision has been depending on the utility maximization behavior of customers where discrete set of alternatives are available for a customer. Then the utilities for each alternative can be modeled as a function of their attributes. However such models of choice, based on rational behavior are not a complete description of customer behavior. Another approach is a normative theory named as Prospect Theory, developed by Kahneman and Tversky, nobel prize winners in 2002. Within this theory, customer choices are not predicted in terms of utility, but in terms of perceived losses and gains and subjective rather than objective probabilities of outcomes. This direction of research still offers potential for deploying these concepts with precision in customer behavior modeling systems. Many other modeling

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techniques such as Bayesian, complexity modeling and other approaches have been used for human behavior. For example, a recent experimental work about choice modeling done with Bayesian approach formulated search, learning and choice set dynamics of customer behavior. In this work, a simulation experiment is carried out to illustrate the construction and evolution of probabilistic mental map for a single individual [2].

Building analytical models that capture customer choice behavior with its entire environment is a challenge on the theoretical and modeling side. An analytical model that captures all demand effects such as customer behavior, supply and external forces simultaneously is almost out of reach. Simulation based techniques are seen as the only realistic way to approach complex demand modeling in the future, even though they are enormously computationally intensive [75]. In this paper, first, advances in travel forecasting models will be presented in the next section. Then conceptual framework of activity-based demand modeling will be described. Finally, different simulations tools for travel forecasting will be compared and future research directions will be discussed in the last sections.

### ADVANCES IN TRAVEL FORECASTING MODELS

In travel forecasting models, network performance is predicted from the interaction between the demand of travelers and the travel options that is supplied to the system. In general terms, travelers' decisions with respect to where, when, and how to travel, as they relate to the service provided by different travel options, is referred to as demand, and the response of the transportation system in terms of travel time, cost, reliability, and other service attributes to a given level of demand is referred to as supply. As it is illustrated in Figure 1, travel demand models represent supply and demand and incorporate a mechanism to determine the outcome of their interactions. These models simultaneously determine both the performance of the network namely capacity utilization and the response of the travelers, thus enabling managers to investigate how to maximize the performance.

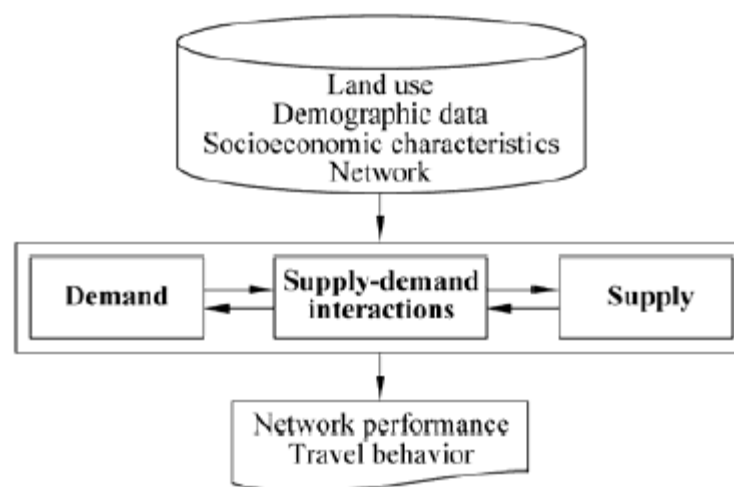


FIGURE 1

Travel Forecasting Framework (Source: Ben Akiva, 2007)

Traditional travel forecasting methods have been long used as aggregate and static estimation models. In the last decades, considerable advances in information technology and increased data availability evolved the demand models and forecasting methods into dynamic disaggregate and stochastic models.

The aggregate representation of travel to disaggregate representation led the focus on representing individual travelers and vehicles/products to capture the heterogeneity of their decisions and movements/changes in availability. As a result of this, the reliance on analytical and closed form mathematical models has decreased but the use of simulation models has increased where traveler and vehicle behavior is implicitly represented through logic incorporated in the simulation model. Related to

this, it has been recognized that deterministic modeling relationships may not be appropriate in all circumstances, so there has been increased interest in accounting for model stochasticity. The dynamic consideration of time is focused on capturing the temporal aspects of traveler behavior (choice of mode, departure time, reaction to time-dependent conditions).

Moreover, the fact that travel is often a by-product of travelers' participation in other activities is ignored in traditional modeling. Whereas, one of the most important underlying factor of travel is that it is triggered by the activities need to be performed at different locations. In this regard, activity-based demand models have been developed in which trips are derived from activities of individuals and households, considering the logical, physical and other constraints.

### CONCEPTUAL FRAMEWORK OF ACTIVITY-BASED DEMAND MODELING

Within the human activity approach to understanding travel behavior, the demand for personal travel is thought to arise from daily requirements for participation in activities outside of the home [38]-[39]. As an alternative to what is typically considered the less behaviorally rigorous trip-based approach, the activity-based conceptualization of urban travel involves constrained patterns or sequences of activities and related travel. Within this framework, travel decisions are thought to emerge through intra-household decision making processes [15]-[38]-[39]-[65]. Another perspective of activity-based travel demand is that decisions are modeled within the household -namely intra-household modeling. The second step in activity-travel process is to describe it within the spatial environment and in time linking the past, present and future activity-travel outcomes. An illustration of the framework of activity-based demand modeling is given in Figure 2.

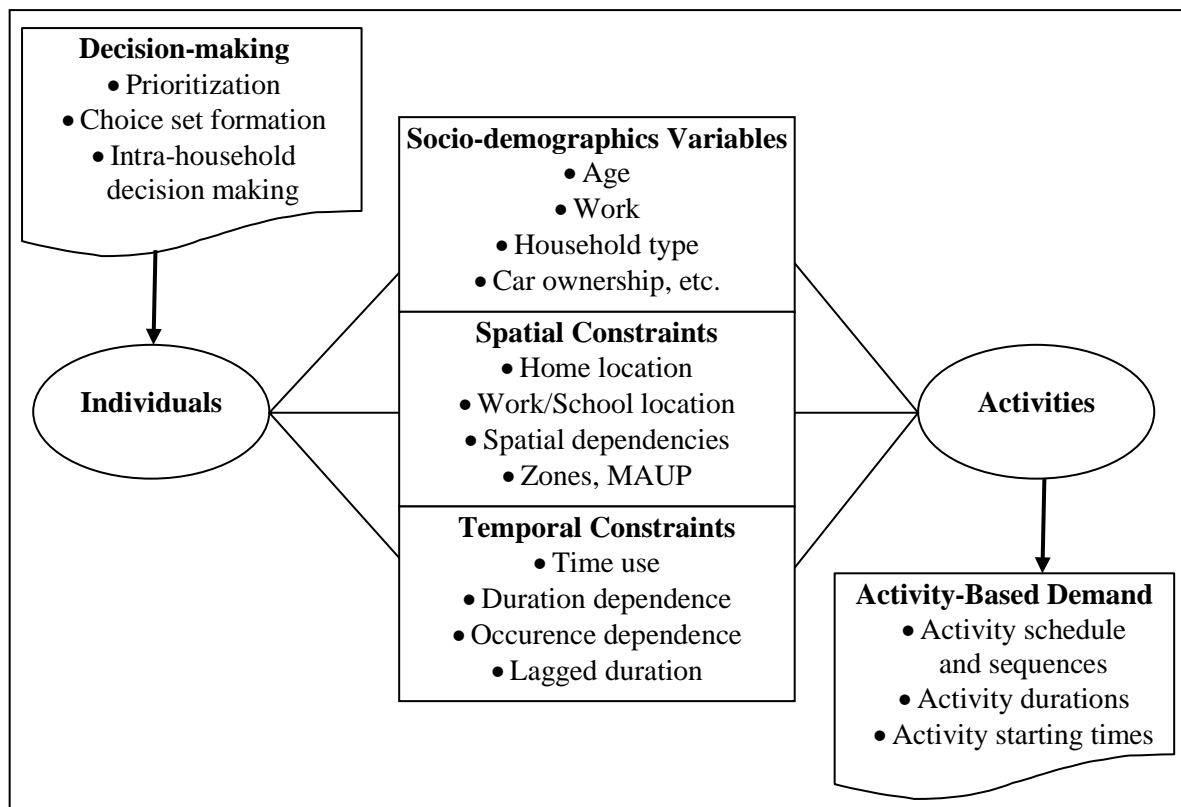


FIGURE 2

Framework for Activity-based demand modeling

An activity-tour or activity-chain can be conceptualized as an entity that begins and ends at the home location and is comprised of travel through a set of intermediate activity stops [13]. One of the more realistic and practical approach which is used commonly is forming the activity chain between the

relatively fixed activity sites (ex. home, work). Besides an activity chain is classified as simple if it has no stops between fixed activity sites otherwise it is called a complex tour when it contains one or more stops between the activity sites [7]-[12]-[13]-[31]-[46]. Modeling the activity chain, the tours are structured with the underlying non-spatial measures, socioeconomic covariates and spatial choice modeling [2]-[14]-[16]-[29]-[41]-[55]-[71].

Another phenomenon of activity scheduling is the prioritization of the activities of the individuals or households. Priority is thought to influence the order of the activity schedules. Models of activity scheduling simulations which link the prioritization with a path dependent activity schedule are used partially for activity-travel outcomes [21]-[22]-[26]-[29]. In this respect the steps are determining the broad range of activity types, classifying the activities such as obligatory (ex. work) and discretionary (ex. leisure, etc.) and finally linking the relationship with the activity schedule. Since some activities are classified as higher priority, first these activities are scheduled and then lower priority activities are settled around the initial obligatory activities. Another aspect of activity prioritization is the fact that it is heterogenous across individuals and households and influenced by the external conditions over time. An effort to understand patterns of prioritization is conducting multiday surveys which are carried out to observe the scheduling of activities through a time horizon of several days [5]-[20]-[48]-[66]-[67]. Until now, activity prioritization is incorporated into scheduling models by assumptions of econometric models [11]-[13], mixed-models [25]-[29]-[47], or microsimulation/agent-based [1]-[18]-[51] approaches.

Besides the classification and prioritization of activities, duration of activities is also a modeling issue. In this respect, mainly, time use researches which set out how individuals spend time on a daily or weekly basis are used. Surveys in this field are undertaken with standard classes for describing the use of time.

Another challenging area of research in travel demand modeling is considering the decision making of individuals within households and modeling the travel demand with respect to individuals as house members. The intra-household decision modeling for activity outcomes requires considering the negotiation and influence of the needs of other members of the house. Some of the research efforts undertaken in modeling are the heterogeneity of household decision processes across households, joint activity participation (in and out of home), gender-based task allocation, collaboration of household activities [27]-[28]-[72]-[73]-[74].

One of the other dimensions of activity demand modeling is the spatial impact. Spatial heterogeneity is that outcomes of a process over space have different distributions changing over space. For example households living in close proximity would have similar behaviors in contrast to the households living far from each other would have distinctive behaviors. This means that spatial analysis of outcomes could form clusters and each cluster will have different mean, variance covariance structures vary from one location to another [6]-[24]-[59]-[37]. Empirically, this is potentially problematic as the presence of spatial dependence violates the independence assumption of regression and other statistical/econometric modeling approaches frequently used in activity-travel research [15]. While autoregressive models (Simultaneous Autoregressive (SAR)), as Reference [6] describe, can capture spatial auto-covariance, Reference [24] describes approaches, such as the spatial expansion method and geographically weighted regression (GWR) that capture local heterogeneity and spatial effects. In a location point of view, zoning and partitioning of zones named as modifiable areal unit problem (MAUP) is a commonly used method in trip-based perspective [17]-[29]-[36]. Even though, the method does not have micro level perspective, in some cases it could give rise to better modeling. Overall, incorporation of the spatial impact into modeling can lead to better parameter estimates and more reliable forecasts which are less biased and more consistent.

Activity-travel outcomes are also need to be analyzed over time. Intuitively, the present activity of an individual is dependent on the past and/or activity/activities of the individual. In this respect, three dependencies are identified, such as duration, occurrence and lagged duration [33]-[34]-[77]. Duration dependence is the conditional probability that the activity will end at a specific time in future. Occurrence dependence refers to the frequency of the activity of an individual taken place in the past [33]. Occurrence dependency can affect the present behavior durations through familiarity, learning, etc. Lagged duration is the effect of time spent in the present activity or any type of previous activity which is related to the

present state [33]. Another area of research is modeling the impact of potential future activities on the present scheduling [4]. Besides, the temporal scale of behavior is also a modeling issue. The human behavior is found to be both “repetitious” and “variable” [32]-[68]. The temporal structure of working and non-working days differ extensively, where repetition is higher and variability of spatial behavior is less in working days whereas in weekends variability is more. In order to investigate and provide accurate behavioral analysis in time empirical research is used commonly and it is suggested to conduct long multi day surveys, such as two week [5]-[16]-[32]-[45]-[61]-[62]-[69]-[70].

## COMPARATIVE REVIEW OF TRAVEL SIMULATION SYSTEMS

Travel simulations are mainly concerned with understanding and modeling relationships between individuals, households, and their spatial movement requirements. The outcomes of the simulations are commonly used to develop or influence policies which are related to the allocation and use of resources. Substantial research and development on modeling approaches and tools have been conducted in the last decades. In this section, a comparative review of the travel simulations and the related tools will be presented.

A well-known method, Monte Carlo method forms a basis for one of the most commonly used travel demand generation technique called as microsimulation. Microsimulation is a travel demand generating application which comprises a process of generating artificial micro-units through time. Recently, microsimulation in activity-travel research has been widely used in demand generating applications due to its benefits of offering behavioral theory incorporation, maintaining the heterogeneity of information during the simulation and minimizing the modeling bias [35]-[49]-[54]-[56]. Microsimulations are deployed both with static models which result in no change of sample structure over time and dynamic models which allows updating of micro-units over time [52]. The micro-units (ex. individuals or households of population) are synthesized from aggregate data with behavioral characteristics [8]. It is a computationally intensive method and has high-quality data requirements in order to create precise micro-units out of aggregate information [49]-[35]. More realistic demand generated by microsimulations is commonly used by macro-level research such as traffic assignment, urban planning, land use analysis, public transportation planning, transportation network performance analysis and evaluation of environmental pollution. Many of these models are integrated in one platform (ILUTE, SAMS, ILUMASS, OPUS) for an entire view of the planning effort. However, here, we will only focus on the activity travel demand generating systems or modules of these systems.

The activity pattern prediction and scheduling tools have extensively used econometric utility maximization and rule-based modeling. Taken the complexity of the activity-travel problem into account, applications such as neural networks, cellular automata, genetic algorithms, evolutionary programming and agent-based modeling are employed in more recent works. Within these applications, agent-based modeling (ABM) drew great attention with record of wide use in pedestrian movement and interaction. The capabilities of ABM offer to be a promising technique also for the dynamic simulation of activities and transportation interaction.

ABM is a technique for modeling the dynamic state of the system by using autonomous agents which interact with each other, generate cooperative or competitive strategies and execute behaviors. Autonomous agents are capable of responding to stimuli, learning, initiating actions and interacting with other agents and environment. ABM is a very near representation of the real world however the identification of agent characteristics is still an important factor for the modeling [57]. Moreover ABM is also a data-intensive and computationally demanding technique [18]-[51].

After a literature survey, the tools for activity-travel demand simulations are presented in Table 1. In the table, focus of the tool, modeling techniques used, theoretical background, the structure of the tool with respect to its modularity and other coupled procedure, advantages and disadvantages of the tool and the development country of the tool are listed.

## CONCLUSION AND FUTURE DIRECTIONS OF RESEARCH

Microsimulation for activity based travel demand generation has experienced substantial development and growth in application with the recent advances in information technology and the increased availability of detailed data. Activity-based travel demand generation has two main building blocks coupled with attributes and constraints related to them. These are, namely, the generation of populations with representation of the heterogeneity of individuals and the daily activities under temporal (time-related) and spatial constraints. Within simulation-based travel modeling research, the behaviors and choices of the heterogeneous synthetic population and modeling the travel as an outcome of their activities still require further work despite the advances in the last years.

One of the main challenges of microsimulation especially for agent-based modeling is computational intensity of the technique. Therefore, the search for efficient algorithms is crucial for creating a comprehensive system. On the other hand, the time dimension of the simulation runs is still remaining as an open research area. For example the effect of the changes over time such as ageing of the population needs to be modeled in a more realistic framework. Another aspect of the travel demand is its spatial representation and geographical visualization which is offering a challenging further work. In this respect, the integration and use of GIS would help users to evaluate and analyze the outputs of the simulations effectively.

TABLE 1

Comparative Review of Microsimulation tools for Travel Demand Generation

Name	Theoretical Base of the Models	Focus	Advantages/ Disadvantages	System Structure/ Modularity	Place of R&D
<b>PCATS</b> (Prism- Constrained Activity-Travel Simulator)	Time geography of Hagerstrand (1970)	Activity engagement of individuals and relating them to travel	Only a sample of a population can be synthesized; the simulation run is limited to a single day of week		Japan
<b>AMOS</b> (Activity Mobility Simulator)	Time geography of Hagerstrand (1970)	Adaption behavior of individuals to changes in travel environment	Only a sample of population can be synthesized; the simulation run is limited to a single day of week	SAMS module (sequenced Activity- Mobility Simulator)	Japan
<b>STPG</b> (Travel Pattern Generator)		Activity engagement with activity choices of individuals and activity duration	Only a sample of population can be synthesized	Used with traffic assignment procedure to explore CO2 levels in Kyoto	Japan



<b>Starchild</b> (Simulation of Travel Activity Responses to Complex Household Interactive Logistic Decisions)	Computational process modeling	Activity pattern generation from survey data; assignment of activity patterns to synthesized population with spatial and temporal attributes		Used with a procedure of dynamic assignment of trips to road network, use GIS for California	USA
<b>Name</b>	<b>Theoretical Base of the Models</b>	<b>Focus</b>	<b>Advantages/ Disadvantages</b>	<b>System Structure/ Modularity</b>	<b>Place of R&amp;D</b>
<b>MASTIC</b> (Model of Action Space in Time Intervals and Clusters)	Clustering of potential activity places	Individual action space generation, and using clustering of potential activity places determining location and sequence of destinations under spatial and temporal attributes			Netherlands
<b>ALBATROSS</b> (A Learning Based Transportation Oriented Simulation System)	Multi-agent rule-based, data mining techniques for rules	Activity pattern estimation for a population of households based on individual learning with interaction over time	As a rule -based model it is an extension and alternative to econometric utility maximization models. There is no spatial representation of activities, it can be improved and integrated with GIS	3 agents, generating rules for choice by Sandra; scenarios & population by Agnes; schedules with fixed and other activities by Scheduler Engine	Netherlands
<b>RAMBLASS</b> (Regional Planning Model Based on the Micro simulation of Daily Activity Patterns)	Segmentation, choice modeling with conditional probabilities	Activity pattern prediction for segmented population using aggregate time-use data and traffic flow prediction based on time, mode, location and route choices	Size of the population can be synthesized up to 15 million people, visualization of network with GIS		Netherlands

<b>ILUTE/ TASHA</b> (Integrated Land Use, Transportation & Environment/ Travel-Activity Scheduler for Household Agents)	Rule based choice modeling	Modeling of behavior of individuals, households, firms, markets and transportation networks/ generation of activity schedules for individuals in a household	Deployed for long-term evaluation of urban policies, simulation runs in monthly time steps/validation of predicted decisions with survey data and adjustment for rescheduling	ILUTE is an integrated simulation system containing TASHA as a activity- scheduler module	Canada
<b>MATSIM</b> (activity scheduling module)	Genetic algorithms combined with agent- based modeling	Simulating daily activity scheduling in individual level and household level		Traffic microsimulation with route generating and demand generating modules	Ger- many &Swit- zerland

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## AN EFFICIENCY ANALYSIS OF TURKISH CONTAINER PORTS USING THE ANALYTIC NETWORK PROCESS

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**Abstract** — *Turkey is one of the most remarkable countries regarding to its growing container market in the Mediterranean Region. In particular, the efforts and investments that have been poured into Turkish container ports are conspicuous; since approximately 90% of the country's international trade has been handling through maritime transport. 80% of Turkish international trade is being occurred by three main ports of Turkey: Port of Ambarlı, Port of İzmir and Port of Mersin rank first, second and third, respectively. Beside, Port of Trabzon may be taken into account because of its geographical position.*

*In this paper, it is aimed to identify the efficiencies of listed four container ports above, using the framework of the analytic network process. A number of conflicting qualitative and quantitative criteria are considered to evaluate the alternative container ports. Relatively simple and systematic approach, analytic network process, is preferred to handle feedbacks and dependencies among the criteria and alternatives.*

**Keywords** — *Analytic network process, efficiency analysis, container port, Turkey.*

### INTRODUCTION

The logistics activities in Turkey have been improved due to recent developments that are based on the country's strategic and geopolitical location. The transport function of logistics has been provided throughout maritime, land, pipeline and air related logistics services.

The transport sector has a significant role in the economy since Turkey covers an extensive area: surrounded by three seas to the south, north and west. Turkey's coast lines which encompass it on three sides with the Mediterranean Sea on the south, the Black Sea to the north and the Aegean Sea to the west which seems as a natural dock, make country open to entire world and supply a major competitive advantage in international logistics. In the northwest of Turkey, there is also an inland Sea of Marmara that connects the Black Sea with rest of the world through Istanbul and Canakkale Straits. Turkey has a land bridge position both in East-West and South-North axes within relationship with the Middle Asian Turkic Republics.

In this paper, it is aimed to identify the efficiency of four container ports in four different locations in Turkey, using the framework of the Analytic Network Process (ANP). The ANP is a simple and systematic approach that can be used by decision makers in various areas. Essentially, it is a more general form of the analytical hierarchy process (AHP), first introduced by Saaty [9]. The ANP, tolerates complex interrelationships between the criteria and decision levels, but the decision-making structure in the AHP model uses unidirectional hierarchical relationships among the decision levels [9]- [10]. The evaluation criteria for analysis of container ports are generally not independent of each other but are often interactive. Due to the different levels of criteria interacting with each other simultaneously in the container port evaluation process, an invalid and unexpected result can be obtained in the face of this complexity. To deal with this problem and to handle interdependence among the criteria at different levels within the model, the ANP approach is used.

The remainder of the paper is organized as follows: first section describes the characteristics of four ports in Turkey. Then ANP methodology is reviewed and evaluation criteria are explained in detail. At the last section obtained results for container port evaluation with ANP methodology are discussed and conclusion remarks are presented.

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## **OVERVIEW OF THE CONTAINER PORTS IN TURKEY**

There are about 186 coastal facilities in Turkey, with various capacities. 64 ports are operated by public organizations. Marmara Region seems like the centre of the agglomeration of coastal facilities. In 2007, Turkey's ports handled more than 4,7 million TEU. Container handling capacity grows around 20% per year, two times bigger than the world average. As a region, Marmara has the greatest container volume in Turkey. In respect of the data of Undersecretary of Maritime Affairs, a significant volume of the sustained increase in maritime container volume (almost 65% of all containers) is handled by the ports which have been mentioned in this paper [15].

Turkey launched to give more emphasis on port privatization, in order to raise the productivity and efficiency of ports. In different capacities and locations, 16 ports have already been privatized. The rest 5 ports are operated by Turkish State Railways (TCDD) and in the agenda of the government's privatization program. Port of Trabzon and Mersin have been already privatized. The privatization process is going on for Port of İzmir. Private sector belongs to Port of Ambarlı as long as it's established.

The share of maritime transportation in world trade is about 80% while it's 86% in Turkey. Year by year, share of maritime in weight is decreasing while any other mode is increasing. It is vice versa for the value. 86 % of the volume of Turkey's foreign trade transportation have been carried by maritime meanwhile 11,9 % has been carried by road, 1,2 % by rail, 0,2 % by air, 0,7 % by other transportation modes. The increasing ratio of containerization per year in the world is ~ 8%, while ~ 20% in Turkey. The projections refer that developments in Turkey's container market will be continued increasingly. In terms of foreign trade cargoes transported by maritime, the major segments of the export goods are 17.7 % iron and steel products, 11.0 % oil products and 8.2 % cement. Major segments of the import goods realized totally as 127.0 million tons are 25 % crude oil and products, 14.9 % coal and 14.9 % iron ore and scrap iron [14]-[15].

The majority of container transportation to/from Turkey depends on the feeder services mainly from Gioia Tauro, Port Said, Piraeus. 221.410 total TEU capacity of 208 vessels being deployed on regular Liner Services that call at Turkish Ports in 2004 including global carriers such as Maersk, MSC, P&O Nedlloyd, Evergreen, NYK, APL, Hapag-Lloyd and so on [3].

### **Port Of Ambarlı**

Marmara Region is known for its vast contributions to the Turkish economy. It is the most populated and most industrialized region of Turkey and composes the fastest increase in traffic of any Turkish region. The highest performed port is Ambarlı which was ranked 57th of the world container ports list in 2005 is in Marmara Region, 34 km away from Istanbul. Ambarlı is the greatest container handling port in Turkey since 2003. Port of Ambarlı was established in 1996 to response Turkey's vital need for container terminal investments and operations to accommodate the rising volume of imports and exports in Marmara Region. Port of Ambarlı is consisting of six individual ports: Kumport, Akçansa, Mardaş, Marport, Set Çimento AŞ., Total Oil Co.orp.

The operations have been providing by private service firms since 1996 to ensure consistent and reliable service at the port. This firm provides the fast and high quality service in the operation of the equipment as well as maintenance and repair. Sub-contractors provide yard cargo loading / discharging customs inspection and sampling and a full range of other services as needed. The port has a flexible management system so as to serve clients' preference. Coordination in terminals is being managed by the firm, called Altas. Particularly Port of Ambarlı use high level operation and information systems.

Container throughput grew annual rate of 40% and around 1,8 million TEU handled in 2007. Port of Ambarlı has a wide spreading hinterland including almost all of the Marmara Region (Figure 1)

### **Port Of Trabzon**

Although Turkey has the longest coasts in Black Sea, this region is the least developed in Turkey in terms of maritime transport. Trabzon is located on the historical Silk Road and a trade gateway to Iran at the east, Russia and Caucasus at the north. Silk Road had started in China and followed different routes after Central Asia, the northern route reached Trabzon and precious goods of the east shipped from the port destined to Europe.





FIGURE 1  
The Hinterland of the Ports

Port of Trabzon has a great potential to play an important role to connect Iran, Iraq, Azerbaijan, Armenia, Uzbekistan and Turkmenistan to Europe and international markets. But various reasons do not allow the Port to be powerful and effective. Some of the reasons are internal: Insufficient/ inadequate physical infrastructure, draft problems, low productivity, untidy port traffic, difficulties of switch to automation. Some of the reasons are external: Complexity and inadequacy of legal regulations related to port services, weak cooperation between port authorities and their intermodal partners in order to improve supply chain performance, insufficient collaboration among institutions and high costs in total logistics process. Until the privatization date of 22nd December, 2003, the Port used to be managed by TDİ (Turkish Maritime Corporation).

Container throughput of Port of Trabzon is the least among the mentioned other ports. Except last years, Port of Trabzon looks like a regional port with steady performance (Table 1).

TABLE 1  
Container Throughput in terms of Years

	2000	2001	2002	2003	2004	2005	2006	2007
<b>TRABZON</b>	1.176	1.084	1.266	2.699	2.442	1.606	5.432	19.216
<b>İZMİR</b>	464.455	491.277	573.231	700.795	804.565	784.377	771.937	
<b>MERSİN</b>	193.894	299.376	294.734	467.109	532.999	596.000	644.000	792.270
<b>AMBARLI</b>	369.560	358.022	549.884	774.959	1.078.406	1.186.041	1.446.267	1.850.000
<b>TÜRKİYE</b>	1.589.777	1.533.457	1.933.218	2.496.390	3.081.351	3.301.140	3.822.757	4.708.160

#### Port of İzmir

Port of İzmir locates in the Aegean Sea and situates at the pivotal point of the sea trade between Western Europe and North Africa. It has a vast agricultural and industrial hinterland and plays a substantial role not only essential core for the industry and agricultural trade in the Aegean Region but also as a vital function in the Turkish exports. İzmir is a city which has enjoyed the benefits and advantages of being located in a trade and harbor region throughout the history.

Port of İzmir is a centre for transshipment cargoes arriving through Black Sea markets, but the port has a limited draft of approach channel and congestion problems. Although Port of İzmir has a great potential such as being close to the Black Sea market, the infrastructure of the port is insufficient to be a transshipment centre. The transit containers originating from Greece (Thessalonica / Piraeus) arriving at the Port of İzmir might be transported to Asian countries by both rail and road connections.

The Port is being operated by TCDD and the recently it has been under privatization process. Container throughputs at the Port of İzmir do not grow steady. Last four years witnessed its decrease in terms of container volume (Figure 2). The extending privatization process is not constructive for the port.

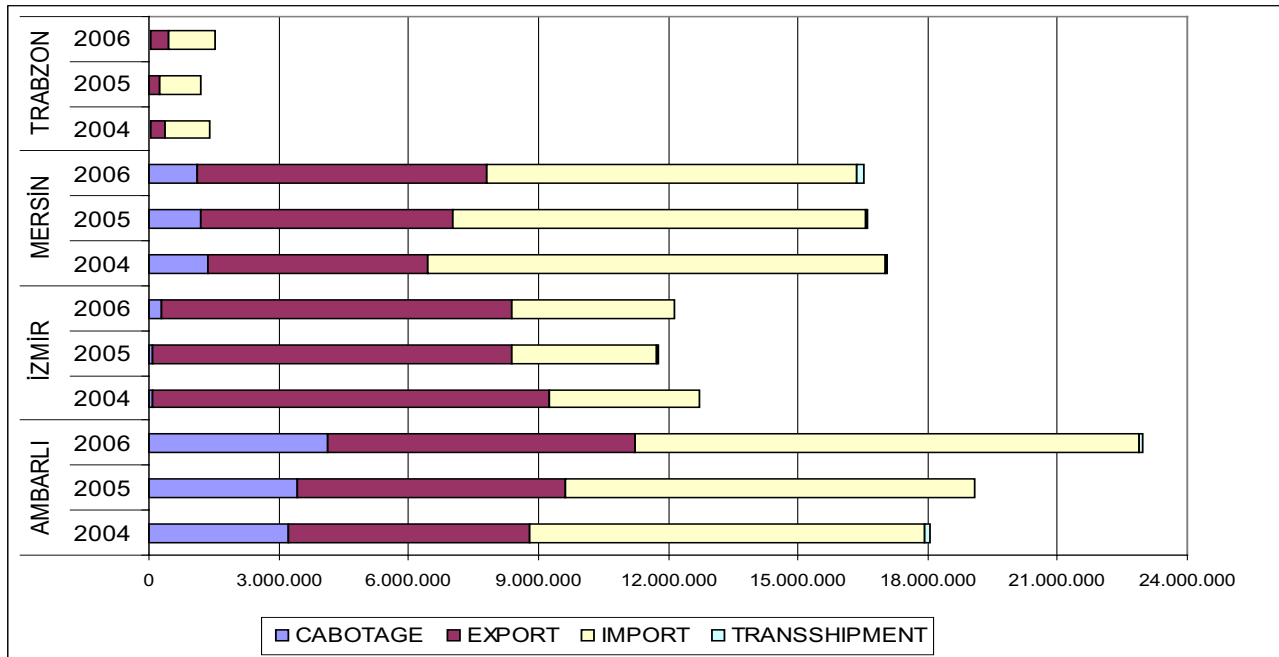


FIGURE 2  
The Cargo Volumes of the Ports [14]-[15]

### Port of Mersin

The main container navigation route between Western Europe and Far East are very close to Port of Mersin. Transit cargoes gain Turkey give attention to Port of Mersin due to Middle East markets connection by road and rail. The port has road (TEM, Asian Highway) and rail (E rail network, TAR, AGTC) connections within the international transport corridors and has an extensive hinterland, suitable for serving to the Middle East countries. Port of Mersin is the unique container and transshipment port in the Mediterranean Sea coast. The port already handles more than 99% of Turkey's container market in the Mediterranean Coast. The size of container terminal is the biggest in Turkey besides Port of İzmir.

Mersin Free Zone is established just adjacent to Mersin Port. Mersin Free Zone is a very important gate for Turkey's foreign trade with regard to its location. Due to the Free Zones adjacent location to the Port, both free zone and port delegates mentioned the positive advantages of this structure. It is the unique model in Turkey that a free zone is adjacent to a port. After the privatization (11th May, 2007), PSA-Akfen joint venture have been managing the port. Although the long privatization process caused some operational problems, the port achieved around 10% rate and 800 thousand TEU in 2007.

## EMPIRICAL ANALYSIS WITH ANP

In this section, the ANP methodology and the calculation steps of it are summarized firstly. Then the structure of the constituted ANP model of container port analysis is described and the chosen evaluation criteria are explained.

### The ANP Methodology

The ANP is a comprehensive framework available for the analysis of alternative actions in various areas. It allows both interaction and feedback within clusters of elements (inner dependence) and between clusters (outer dependence). The feedback element captures the complex effects of interplay in human society, especially when risk and uncertainty are involved. The elements in a cluster may influence other elements that are in the same cluster or in other clusters with respect to several properties. The main objective in the process

is to determine the overall influence of all the elements in conjunction with each other [7]-[10]. The modeling process can be divided into three steps for ease of understanding.

The first step is the pair-wise comparisons and relative weight estimation. All the relations within the clusters of elements and between clusters are evaluated as pair-wise comparisons. A reciprocal value is assigned to the inverse comparison. Once the pair-wise comparisons are completed, such as the AHP, a local priority vector (eigenvector),  $w$ , is computed as an estimate of the relative importance of the elements compared by solving the following equation:

$$Aw = \lambda_{\max} w, \quad [1]$$

where  $\lambda_{\max}$  is the largest eigenvalue of the pair-wise comparison matrix,  $A$ .

The second step is related with the formation of the initial supermatrix. All the obtained priority vectors are then normalized to represent the local priority vector. To obtain global priorities, the local priority vectors are entered in the appropriate columns of a matrix of influence among the elements, known as a supermatrix. The initial supermatrix must be transformed to a matrix in which each of its columns sums up to unity. For this reason, this matrix must be normalized using the weight of the cluster to achieve the unit columns. Thus, the stochastic or weighted supermatrix is obtained [2]-[8]. The supermatrix representation of a hierarchy with three levels is as follows:

$$W = \begin{matrix} & \begin{matrix} G & C & A \end{matrix} \\ \begin{matrix} Goal(G) \\ Criteria(C) \\ Alternatives(A) \end{matrix} & \begin{pmatrix} 0 & 0 & 0 \\ W_{21} & 0 & 0 \\ 0 & W_{32} & I \end{pmatrix} \end{matrix}, \quad [2]$$

where  $W_{21}$  is a vector that represents the impact of the goal on the criteria,  $W_{32}$  is a vector that represents the impact of the criteria on each of the alternatives, and  $I$  is the identity matrix.  $W$  is referred to as a supermatrix because its entries are matrices. For example, if the criteria are dependent among themselves, then the (2,2) entry of  $W$  given by  $W_{22}$  would be nonzero. The interdependency is shown by the presence of the matrix element,  $W_{22}$ , of the supermatrix  $W$  as follows:

$$W = \begin{pmatrix} 0 & 0 & 0 \\ W_{21} & W_{22} & 0 \\ 0 & W_{32} & I \end{pmatrix}. \quad [3]$$

The last step is the formation of the weighted and limit supermatrix. Here, the cluster in each column of the supermatrix  $W$  is weighted, and the result, known as the weighted supermatrix, is stochastic. Because  $W$  is a column stochastic matrix, it is known that the synthesis of all the interactions among the elements of this system is given by  $W^\infty$ . Raising  $W$  to powers gives the long-term relative influences of the elements on each other. To achieve convergence of the importance weights, the weighted (stochastic) supermatrix is raised to power. Finally, the obtained numbers are the priorities of the alternatives.

### ANP Model for Container Port Evaluation

The structure of the proposed model is described in Figure 3. The goal is determined as “comparing the alternative container ports”. Then the criteria clusters and the sub-criteria are chosen considering the container port situations in Turkey and considering the literature [5]-[1]-[11]-[4]. Ambarlı, İzmir, Mersin and Trabzon container ports are taken as the alternatives due to the reasons mentioned in previous sections.

Port location (PL) criteria cluster influences the hinterland and overall cost adversely. When the port location is looked through overland transportation, distance from hub port to the reaching station is one of the biggest items of cost. “Proximity of the hub port” (PL1) changes the costs by setting the shipping distance. “Proximity to the main navigation route” (PL2) will also change the cost, since it changes the shipping distance.

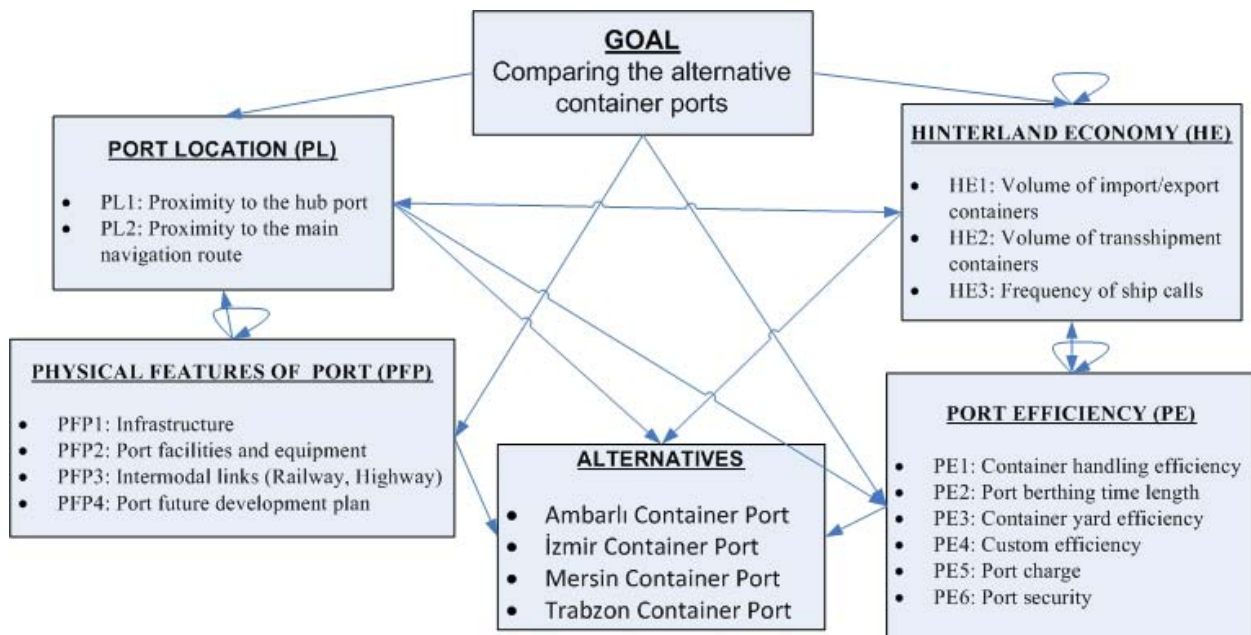


FIGURE. 3  
Structure of The ANP Model

Hinterland Economy (HE) criteria cluster includes three sub-criteria. “Volume of import/export containers” (HE1) and “Volume of transshipment containers” (HE2) are the sub-criteria which define the potential number of containers in the hinterland. The last one (HE3) is “frequency of ship calls” to the desired routes and it is important for the transportation companies that transport merchandises periodically. Frequency of import/export shipment merchandise changes the inventory and the costs (economics of scale). Frequency is also connected with the size of the port and the number of agents in the port.

Physical Features of Port (PFP) criteria constitute the third cluster. In general, ports require high performance, special handling equipments and convenient facilities for mass cargo movements. Therefore “Port infrastructure” (PFP1) and “Port facilities and equipment” (PFP2) are chosen as selection sub-criteria. Because of the growing of containerized cargo, especially at the main routes, the transportation should be realized more efficiently. Therefore, “Intermodal links” (PFP3) can be a key criterion in terms of efficiency and it is chosen as a selection sub-criterion. “Port future development plan” (PFP4) sub-criterion means the changes and investments that will be done by port. The aim is to find out the relation between the effect of a certain plan on criteria and the effects of criteria on this plan.

Port Efficiency (PE) criteria cluster includes six sub-criteria. First one is “Container handling efficiency” (PE1) and it decreases the time spent on conveyance inside the port and loading and unloading of freights. Lower time means reduced cost. “Port berthing time length” (PE2) affects the time spent at ports. At ports, waiting time for a container at the yard can overrun a week. Therefore, “Container yard efficiency” (PE3) is chosen as another sub-criterion. As the last one, “Custom efficiency” (PE4) represents the remaining efficiencies, like speed of bureaucratic processes. Another important criterion is “Port charge” (PE5) and the evaluation of ports’ charges by the ANP technique is left to the experts. At last, by “Port security” (PE6) sub-criterion, all security precautions are meant. It is needed to be taken notice that all ports must meet IMO (International Maritime Organization) security standards.

## RESULTS OF THE EFFICIENCY ANALYSIS

Four container ports which have their own hinterlands are compared in terms of their places in local market and the obtained results are summarized below.

The weights of the efficiency evaluation criteria are determined as: %45 for port location, %25 for hinterland economy, %22 for port efficiency, and %8 for physical features. When the international trade volumes are considered in these ports, the import-export freights of the hinterlands have a big role. Therefore, the port location criterion has the biggest importance. The hinterland economy is in the second rank since the volume of import-export freight is fed by the hinterland of the port. If the study was focused on the transshipment freights, the weight of the physical features would be higher. However, the evaluated four

container ports can be supposed as monopoly in their locations and there is not any competitor in terms of the physical features. As a result, physical features and cost factors have relatively lower weights.

The weights of the sub-criteria and the interactions and feedbacks within clusters and between clusters are also very important. The sub-criteria of the port location have higher weights in comparison with the remaining ones. Because of the considered container ports are not on the line of mother ships, proximity to the hub-ports is more important than proximity to the main navigation route. Frequency of ship calls is the following sub-criteria. The reason is the assumption of accepting both of the export-import and transshipment freights. The remaining sub-criteria have the similar weights as ranked in Table 2.

TABLE 2  
Weights of the Sub-criteria

Sub-criteria	Weight	Sub-criteria	Weight
- PL1: Proximity of the hub port	0.272246	- PE2: Port berthing time length	0.028528
- PL2: Proximity to the main navigation route	0.181498	- PE4: Custom efficiency	0.028528
- HE3: Frequency of ship calls	0.117394	- PE6: Port security	0.028528
- HE1: Volume of import/export containers	0.088045	- PFP1: Infrastructure	0.02666
- PE5: Port charge	0.051351	- PFP3: Intermodal links (Railway, Highway)	0.023327
- HE2: Volume of transshipment containers	0.044023	- PFP2: Port facilities and equipment	0.016662
- PE1: Container handling efficiency	0.03994	- PFP4: Port future development plan	0.01333
- PE3: Container yard efficiency	0.03994		

Considering the relation between criteria and sub-criteria and their weights, the precedence of the container ports are obtained as: %34 for Mersin, %27 for Ambarlı, %26 for İzmir, and %13 for Trabzon Port. The most efficient Port of Mersin has taken the highest precedence for both of the sub-criteria of port location with Port of İzmir alternative. Also the highest share of the transshipped freight in 2006 belongs to the Mersin. By completing the privatization process, Port of Mersin which is enhanced and invested physically, increased its importance after the Ambarlı. Intermodal links are the strength side in terms of the railway and highway connections for the hinterland. Because of the privatization, future plans are satisfying but port charges are ranked it in second place.

The highest import-export freight share in 2006 belongs to Port of Ambarlı since it is in an important production and consuming center. Port of Ambarlı belongs to private sector and this situation provides many advantages in terms of infrastructure and physical features. Accessibility of the Port is poor because of not having a railway connection and being in the Istanbul traffic. Also the future plans for Port of Ambarlı is poor because of its lack of expansion area in the urban and earthquake risk in Istanbul. Also, Ambarlı is the most expensive Port and has taken the worst value for these sub-criteria.

Continuing privatization process for Port of İzmir causes some difficulties. There is not any convincing infrastructural or physical investment yet. This situation affects the future plans negatively. After all, it has taken the highest priority for port charges because of being the cheapest one.

Port of Trabzon is the worst alternative for port location criterion. Volume of the import-export and transshipment freights is the lowest in Trabzon Port. Physical features were improved in last two years and this increased the handled freight volume in the port. Trabzon also does not have a railway connection or sufficient highway accessibility. The positive future plans and low port charges increase the all kind of freight volume.

## DISCUSSION AND CONCLUSION REMARKS

Turkey is known as a bridge among three continents but unfortunately it not used efficiently. Hence, the structure of transit transportation does not constitute an income for the national economy. In this regard, the subject should have a government policy and all the physical and economical plans should realized considering with this policy. As it is seen in this study, the efficiency of the ports is mostly related with the approximation to hub port and to main navigation route. For this reason, it should be struggled to make at least one port as global or mother port in Turkey.

According to this study, Mersin Port is the most strength alternative for mother port. If efficient connections with other transportation modes are constructed, vertical transportation from Mersin to Trabzon Port may be a probable alternative to using Mediterranean, Aegean, Marmara Sea and Bosphorus. This makes easier to being a bridge for transit transportation. Connection between railway and sea modes will provide to use more efficient the potential hinterlands like Trabzon and Ambarlı Ports. Even there are railway connections in Mersin and İzmir Ports, %5-10 of the overall freight is transported by this way.

Another important point is related with port charges. Port charges and the overall logistics costs should be lowered to make the ports more efficient. Therefore, the infrastructure of the ports should be improved, the logistics activities should be realized faster, and custom regulations should be revised. More accoutered and organized logistics villages may be a step for decreasing the cost factor. Considering with above mentioned points, Mersin Port may taken as a model for the other ports. Although the some disadvantages of Mersin Port, it is in better position in many criteria in comparison to remaining ports. In future studies, same evaluation method may be applied on different functional areas of the Mersin Port to determine the weak sides of it for being a mother port.

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# A MULTI-OBJECTIVE APPROACH TO DESIGNING A MULTI-COMMUNITY SUPPLY CHAIN DISTRIBUTION NETWORK WITH MULTIPLE CAPACITIES

Gholam Reza Nasiri<sup>1</sup>, Hamid Davoudpour<sup>2</sup> and B.Karimi<sup>3</sup>

**Abstract** — In this research, an integrated multi-objective distribution model is developed for use in simultaneous strategic and operational supply chain (SC) planning. The proposed method is adopted to allow use of a performance measurement system that includes conflicting objectives such as distribution costs, customer service level (safety stock holding), resource (warehouse space) utilization and the total delivery time with reference to multiple warehouse capacities and uncertain forecast demands. Moreover, this model incorporates inventory decisions into facility (warehouses/distribution centers) location model in supply chain design. Computational results support our assertion that stochastic goal programming approaches can effectively be used in handling the collaborative location/allocation problems in different supply chain structures.

**Keywords** — Supply chain design, location-allocation problem, Mathematical programming, Multi-objective decision making, Multi-level capacitated warehouses.

## INTRODUCTION

The distribution planning decision (DPD) is one of the most comprehensive strategic decision issues that need to be optimized for the long-term efficient operation of whole SC. The DPD involves optimizing the transportation plan for allocating goods and/or services from a set of sources to various destinations in a supply chain [1]. An important strategic issue related to the design and operation of a physical distribution network in a supply chain system is the determination of the best sites for intermediate stocking points, or warehouses. The use of warehouses provides a company with flexibility to respond to changes in the marketplace and can result in significant cost savings due to economies of scale in transportation or shipping costs.

In this paper we present a novel supply chain design (SCD) model consisting of one manufacturer and multiple distribution centers (warehouses) which integrate the location/allocation and distribution plans considering various conflicting objectives simultaneously as well as the imprecise nature of some critical parameters such as market demands, cost/time coefficients and capacity levels. We also incorporate the tactical/operational decisions into the facility location problem solution scheme. Specifically, inventory decisions will be simultaneously modeled with the distribution network design. This inclusion acquires especial relevance in the presence of high holding costs (e.g. frozen food industry) and high-variability demands. We consider three important objective functions:

The paper has two important applied and theoretical contributions. First, it presents a new comprehensive and practical, but tractable, optimization model for supply chain designing. And second, it introduces a novel solution procedure for finding more non dominated and efficient compromise solution to a stochastic multi-objective mixed-integer program.

The remainder of this paper is organized as follows. In next Section we define our notation, state our assumptions and propose a new multi-objective stochastic mixed integer nonlinear program (MOSMINLP) for the proposed SCD problem. After applying appropriate strategies for converting the stochastic model into a multi-objective nonlinear model (MONLP), we propose a novel interactive payoff approach to solve this MONLP and find an efficient compromise solution. The proposed model and solution method are validated through numerical tests. The data for these numerical computations have been inspired by a real life industrial case as well as randomly generated data. Conclusion remarks about our computational results are summarized the last Section.

## PROBLEM DESCRIPTION AND FORMULATION

We consider a firm that owns a manufacturing plant capable of producing multiple products. The products are then delivered to different distribution centers (warehouses/wholesalers) in order to satisfy their associated dynamic demands.

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## Problem description, assumptions and notation

The stochastic multi-objective DPD problem examined here can be described as follows:

- In the case analyzed in this paper, the plant location is known and fixed. The network considered encompasses a set of retailers with known locations, and possible discrete set of location zones/sires where the plant and warehouses are located.
- The final products have stochastic retailer demand over a given finite planning horizon with mean  $d_{il}$  and variance  $v_{il}$  (note here that our customers are mostly retailers not end consumers).
- A storage capacity at each warehouse has multiple values (five level storage capacities).
- The distribution costs and delivery time on a given route is directly proportional to the units shipped.
- Products are independent to each other, related to marketing and sales price.
- Retailers are supplied each product from single DC.

The indices, parameters and variables used to formulate the problem mathematically are described below.

Indices:

$i$	index set of customers/customer zones ( $i=1, \dots, I$ )
$j$	index set of potential warehouse sites ( $j=1, \dots, J$ )
$l$	index set of products ( $l=1, \dots, L$ )
$h$	index set of capacity levels available to the potential warehouses ( $h=1, \dots, H$ )
$g$	index for objectives for all $g=1, 2, 3$
$\eta$	Investment cost performance index $[0, 1]$
$\gamma$	delivery time performance index $[0, 1]$
$K$	customer service performance index $[0, 1]$
$Z_{1-\alpha}$	Normal distribution value for system service level

Parameters:

$TC_{ijl}$	unit cost of supplying product $l$ to customer zone $i$ from warehouse on site $j$
$TC_{jl}$	unit cost of supplying product $l$ to warehouse on site $j$ from the plant
$t_{ijl}$	delivery time per unit delivered to customer zone $i$ from warehouse $j$ for product $l$
$t_{jl}$	delivery time per unit delivered to warehouse $j$ from the plant for product $l$
$LT_{jl}$	the elapsed time between two consecutive orders of product $l$ for site $j$
$F_{jh}$	fixed cost per unit of time for opening and operating warehouse with capacity level $h$ on site $j$
$d_{il}$	mean demand per time unit of product $l$ from customer zone $i$
$v_{il}$	variance of the demand per unit product $l$ from customer zone $i$
$HC_{jl}$	holding cost per time unit of product $l$ in warehouse on site $j$
$OC_{jl}$	ordering cost of product $l$ from warehouse on site $j$ to the plant
$cap_{jh}$	capacity of warehouse on site $j$ with capacity level $h$
$s_l$	space requirement of product $l$ at any warehouse

Decisions variables:

$X_{jh}$	it takes value 1, if a warehouse with capacity level $h$ is installed on potential site $j$ , and 0 otherwise
$Y_{ijl}$	it takes value 1, if the warehouse on site $j$ serves product $l$ of customer $i$ , and 0 otherwise
$D_{jl}$	mean demand per time unit of product $l$ to be assigned to warehouse on site $j$
$V_{jl}$	variance of the demand per time unit of product $l$ to be assigned to warehouse on site $j$

## Stochastic multi-objective non-linear programming model

**Objective functions-** This work selected the multi-objective functions for solving the DPD problem by reviewing the literature and considering practical situations. In practice, most DPD problems minimized total production costs, transportation costs and delivery time [2]-[3]. In particular, these objective functions are normally stochastic or fuzzy in nature owing to incomplete and/or uncertain information over the planning horizon. Accordingly, three objective functions were simultaneously considered in formulating the original stochastic DPD problem, as follows:

- Minimize total Investment (INV) in opening DCs/warehouses:

$$\text{Min } Z_1 = \sum_{j=1}^J \sum_{h=1}^H F_{jh} \cdot X_{jh} \quad (1)$$



- *Minimize total cost (TCOST)*

This objective function contains (see Miranda and Garrido[4]):

- Transportation cost of products from the plant to warehouses and from warehouses to retailers,
- Holding cost for mean inventory and safety stocks

$$\begin{aligned} \text{Min } Z_2 = & \sum_{i=1}^I \sum_{j=1}^J \sum_{l=1}^L (TC_{jl} + TC_{ijl}) \cdot d_{il} \cdot Y_{ijl} \\ & + \sum_{j=1}^J \sum_{l=1}^L \sqrt{2 \cdot HC_{jl} \cdot OC_{jl}} \cdot \sqrt{D_{jl}} + \sum_{j=1}^J \sum_{l=1}^L HC_{jl} \cdot Z_{1-\alpha} \cdot \sqrt{LT_{jl}} \cdot \sqrt{V_{jl}} \end{aligned} \quad (2)$$

- *Minimize total delivery time (TDELT)*

$$\text{Min } Z_3 = \sum_{i=1}^I \sum_{j=1}^J \sum_{l=1}^L (t_{jl} + t_{ijl}) \cdot d_{il} \cdot Y_{ijl} \quad (3)$$

### Constraints

- Constraints for assures that each retailer is served exactly for each product by one warehouse (single source):

$$\sum_{j=1}^J Y_{ijl} = 1 \quad \forall i = 1, \dots, I, \quad \forall l = 1, \dots, L \quad (4)$$

- Constraints on warehouse capacity:

$$\sum_{i=1}^I \sum_{l=1}^L d_{il} \cdot s_l \cdot Y_{ijl} \leq \sum_{h=1}^H \text{cap}_{jh} \cdot X_{jh} \quad \forall j = 1, \dots, J \quad (5)$$

- These constraints compute the served average demand by each warehouse:

$$\sum_{i=1}^I d_{il} \cdot Y_{ijl} = D_{jl} \quad \forall j = 1, \dots, J, \quad \forall l = 1, \dots, L \quad (6)$$

- These constraints compute the total variance of served demand by each warehouse:

$$\sum_{i=1}^I v_{ijl} \cdot Y_{ijl} = V_{jl} \quad \forall j = 1, \dots, J, \quad \forall l = 1, \dots, L \quad (7)$$

Implicitly we assume that the demands are independently distributed across the retailers, thus all the covariance terms are zero.

- These constraints ensure that each warehouse at most one capacity level, can be assigned.

$$\sum_{h=1}^H X_{jh} \leq 1 \quad \forall j = 1, \dots, J \quad (8)$$

- Binary constraints on decision variables:

$$X_{jh} \cdot Y_{ijl} \in \{0, 1\} \quad \forall i = 1, \dots, I, \quad \forall j = 1, \dots, J, \quad \forall l = 1, \dots, L, \quad \forall h = 1, \dots, H \quad (9)$$

## THE PROPOSED SGP-BASED SOLUTION APPROACH

**Defining goals of the objective functions**-As we know, the stochastic goal programming (SGP) needs an aspiration level for each objective. These aspiration levels are determined by DMs. In addition to the aspiration levels of the goals, we need max-min limits ( $u_g, l_g$ ) for each goal. While the DMs decide the max-min limits, the linear programming results are starting points and the intervals are covered by these results. But note that in non-linear programming (with minimum objective) the minimum limit for any non-linear objective may be calculated by another objective. This situation may be appeared because the optimum point may be is local optimum [5].

By use of the interactive paradigm, interactive stochastic multi-objective decision making approaches have been investigated to improve the flexibility and robustness of multi-objective decision making techniques. They provide learning process about the system, whereby the DM can learn to recognize good solutions and relative importance of factors in the system [6]. The main advantage of interactive approaches is that the DM controls the search direction during the solution procedure and, as a result, the efficient solution achieves his/her preferences.

### Solution methodology

To deal with multi-objective and enable the decision makers (DM) for evaluating a greater number of alternative solutions, three different approaches are implemented in this section.

**Approach 1.** In this approach weights of objective  $Z_1$  and  $Z_2$  are specified with  $W_1$  and  $W_2$  as follows:

$W_1$  : Set of weights for *INV* objective function (  $w_1, w_2, w_3, \dots$  ) and

$W_2$  : Set of weights for *TCOST* objective function (  $1-w_1, 1-w_2, 1-w_3, \dots$  ) (10)

Note that in this approach based on presented three objective functions and preferred DM's level of service, we generate several scenarios and don't consider the *TDEL* objective. So problem 1 can be summarized as follow:

**Problem 1:**  $Z_{p1} = \text{Min } W_1 Z_1 + W_2 Z_2$   
Subject to: (4)-(9) (11)

**Approach 2.** In this approach weights of objectives (  $Z_1, Z_2$  ) and preferred DM's level of service are the same as approach 1, but we consider  $Z_3$  (*TDEL* objective) as a new constraint.

**Problem 2:**  $Z_{p2} = \text{Min } W_1 Z_1 + W_2 Z_2$   
Subject to:  $Z_3 \leq Z_{33} + \gamma Z_{33}$   
(4) - (9) (12)

In payoff table we calculated optimum (or local optimum) value for the three objectives [5]. Because of objective  $Z_3$  and  $Z_2$  are very interactive, it is important for DMs that peruse the impact of increasing  $\gamma$  % in total delivery time ( *TDEL* ) on system costs ( *INV* and *TCOST* ).

**Approach 3.** In this approach objective function is *TCOST* and the other ones ( *INV*, *TDEL* ) are added to the pervious constraints (4)-(9). Same as approach 2, it is important for DMs that peruse the impact of increasing  $\eta$  % in total investment cost and  $\gamma$  % in total delivery time ( *TDEL* ) on *TCOST* objective function.

**Problem 3:**  $Z_{p3} = \text{Min } Z_2$   
Subject to:  $Z_1 \leq Z_{11} + \eta Z_{11}$   
 $Z_3 \leq Z_{33} + \gamma Z_{33}$   
(4) - (9) (13)

For generating more scenarios we calculate  $\eta$  and  $\gamma$  systematically based on DM preferences.

## CASE STUDY

The case study presented here illustrated the algorithm proposed in section 3, as well as the applicability and effectiveness of the model. This food industries company is the leading producer of two main categories of Iranian food and drinking, rice and tea. Details information is presented in the next sub-section.

**Setup.** A case study inspired by a food producer in Iran is presented for demonstrating the validity and practicality of the model and solution method. The company owns one production site as well as six DCs located in the different customer zones. There are three types of products and twenty main retailers. Lingo 8.0 optimization software is used at the solution stage. All scenarios are solved on a Pentium 4 (Core 2 Duo) with 1GB RAM and 4 GHz CPU.

Because of confidentiality, most of the input data are randomly generated. However, the generation process is done so that they will be close to the real data available in the company. Without loss of generality and just to simplify the generation of stochastic parameters, we apply the pattern of systematical Normal distribution for our numerical test.

## Performance analysis

The interactive solution procedure using the proposed SGP method for the company case study is as follows. First, formulate the original stochastic multi-objective DPD problem according (1)-(9). The goal of the model is to select the optimum numbers, locations and capacity levels of warehouses to deliver the products to the retailers at the least cost while satisfying the desired service level to the retailers. The proposed model distinguishes itself from other models in this field in the modeling approach used. Because of somehow uncertain nature of retailers' demand and DMs' aspiration levels for the goals, stochastic modeling approach is used. Additionally, a novel and generic SGP-based solution approach is proposed to determine the preferred compromise solution. Second, Obtain efficient extreme solutions for each of the objective functions.

It is assumed here that the DMs don't choose any of the efficient extreme solutions as the preferred compromise solution and proceed to the next step.

In our case, the corresponding minimum and maximum values of the efficient extreme solutions are determined as the lower and upper bounds, respectively, as presented in Table 1.

After calculating upper and lower bounds of each objective function, the next step is formulation of problem 1, 2 and 3. Summery of the results for the various scenarios are given in Tables 2, 3 and 4.

As we stated previously, the relative weights for the first and second objective functions in problem 1, can be determined by the DMs using various method. For the presented case study, DMs determined three weights

for *INV* and *TCOST* objectives as follows: (0.7, 0.3), (0.5, 0.5) and (0.3, 0.7). For this problem, no constraints on delivery time were included. So by fixing the value of  $W_1$  and  $W_2$ , the solution given in Table 2 is obtained. In this table for three values of each objective function and three levels for customer service performance index, CSPI ( $K$ ), that DMs determined, nine scenarios have been generated.

Table 1

Lower and upper bounds for the objectives		
Objectives	Lower bound	Upper bound
INV	9,922,500	14,880,000
TCOST	3,407,083	5,386,177
TDELT	33,672,890	53,486,321

Table 2

Solution results of the proposed model by approach 1

Scenario #	Performance vector ( $W_1, W_2, \eta, \gamma, K$ )	Obj. (\$)	# open warehouses	WRL% <sup>a</sup>	CPU time (Sec.)	# constraints
1	(0.5, 0.5, -, -, 97.5)	7,111,742	3	0.9859	44	112
2	(0.5, 0.5, -, -, 90)	6,991,673	3	0.9859	6	112
3	(0.5, 0.5, -, -, 75)	6,988,496	3	0.9859	58	112
4	(0.3, 0.7, -, -, 97.5)	5,828,280	3	0.9859	97	112
5*	(0.3, 0.7, -, -, 90)	6,078,254	5	0.9917	180	112
6*	(0.3, 0.7, -, -, 75)	5,877,230	3	0.9859	9	112
7	(0.7, 0.3, -, -, 97.5)	8,261,421	3	0.9859	8	112
8	(0.7, 0.3, -, -, 90)	8,165,355	3	0.9859	6	112
9	(0.7, 0.3, -, -, 75)	8,163,974	3	0.9859	7	112

<sup>a</sup>WRL= total demand of retailers/total capacity of selective warehouses.

\*Inferior Scenarios.

In table 2, the warehouse load ratio percentage (WRL) column shows the efficiency of the opened warehouses. Average WRL for approach 1 is 0.9865. By considering 6<sup>th</sup> column in the table 2, it can be determined that because of  $Z_{p1}$  is a non-linear objective, the range of CPU time for solving this problem is very wide from 6 to 180 seconds. Note that in scenarios 5 and 6, though that customer service performance (90%, 75%) is lower than 4<sup>th</sup> scenario (97.5%), but the objective function is higher. Then these scenarios are inferior and must be removed from scenario list. Comparing first and third scenarios in Table 2, shows that total cost increased slightly from 6,988,496 to 7,111,742 (1.7%) when CSPI was increased from 75% to 97.5% (23%). This situation is same for scenarios 7, 8 and 9 in approach one and the other scenarios in second and third approaches (Tables 3 and 4). As it can be seen, the effect of customer service level decreasing in cost improvement is inconsiderable. This may support management's preference for a  $K=97.5\%$  because large increase in CSPI results in a small cost penalty. Selecting first or seventh scenario in this approach is based on DMs preferred objective weights. For solving problem 2, first the  $\gamma$  parameter must be calculated based on DMs preferences for the right hand side of the new constraint (*TDELT*). Based on three values for  $W_1$ ,  $W_2$  and  $\gamma$ , eighteen scenarios have been generated. Solution results for these scenarios are presented in Table 3. Average WRL for approach 2 (0.9644) is lower than approach 1 (0.9865). Because of considering *TDELT* objective in approach 2 this effect is sound usual. Considering sixth column in table 3, it can be determined that because of  $Z_{p2}$  is a non-linear objective, the range of CPU time for solving this problem is very wide, from 32 to 1693 seconds. Comparing CPU times in Table 2 and 3, shows that these times for problem 2 are significantly larger than problem 1. Unfortunately, LINGO optimization software couldn't solve 16<sup>th</sup> scenario in 180 minutes. The performance vectors and the other results were presented in Table 4. It is interesting to note here that, average WRL for approach 3 is 0.9878 and is higher than the other approaches.

In summery, we make the following observations from our case analysis:

- The 10 cases out of 33 scenarios were dominated by the other ones.
- Results indicate that proposed model is not very sensitive to CSPI, so that preferred value for this parameter is 97.5%.

## SUMMARY AND CONCLUSIONS

This study proposed a multi-objective, multi-commodity distribution planning model integrating location and inventory control decisions in a multi-echelon supply chain network with multiple capacity centers in a stochastic environment.

Table 3  
Solution results of the proposed model by approach 2

Scenario#	Performance vector ( $W_1, W_2, \eta, \gamma, K$ )	Obj.	# open warehouses	WRL%	CPU time (Sec.)	# constraints
10	(0.5, 0.5, -,0%, 97.5)	8,243,538	6	0.8873	32	113
11	(0.5, 0.5, -,0%, 90)	8,239,363	6	0.8873	55	113
12	(0.5, 0.5, -,0%, 75)	8,235,653	6	0.8873	27	113
13	(0.5, 0.5, -,5%, 97.5)	7,632,590	6	0.9917	360	113
14	(0.5, 0.5, -,5%, 90)	7,445,910	5	0.9862	1693	113
15*	(0.5, 0.5, -,5%, 75)	7,599,068	5	0.9633	10	113
16	(0.3, 0.7, -,5%, 97.5)	-----	--	-----	----	113
17	(0.3, 0.7, -,5%, 90)	5,877,907	5	0.9917	600	113
18*	(0.3, 0.7, -,5%, 75)	5,935,038	5	0.9801	1086	113
19	(0.3, 0.7, -,10%, 97.5)	6,055,389	5	0.9888	360	113
20	(0.3, 0.7, -,10%, 90)	5,942,147	5	0.9859	360	113
21	(0.3, 0.7, -,10%, 75)	5,886,385	5	0.9921	360	113
22	(0.7, 0.3, -,5%, 97.5)	9,143,315	5	0.9801	638	113
23*	(0.7, 0.3, -,5%, 90)	9,174,460	5	0.9525	360	113
24	(0.7, 0.3, -,5%, 75)	9,046,248	5	0.9745	360	113
25	(0.7, 0.3, -,10%, 97.5)	8,838,670	4	0.9745	360	113
26*	(0.7, 0.3, -,10%, 90)	8,999,840	5	0.9859	360	113
27*	(0.7, 0.3, -,10%, 75)	8,998,700	5	0.9859	360	113

\*Inferior scenarios

Table 4  
Solution results of the proposed model by the approach 3

Scenario#	Performance vector ( $W_1, W_2, \eta, \gamma, K$ )	Obj.	# open warehouses	WRL%	CPU time (Sec.)	# constraints
28	(-, -,15%,5%,97.5)	3,523,690	5	0.9859	164	114
29	(-, -,15%,5%,90)	3,515,250	5	0.9859	164	114
30	(-, -,15%,5%,75)	3,507,633	5	0.9859	169	114
31*	(-, -,15%,10%,97.5)	3,557,681	5	0.9917	109	114
32*	(-, -,15%,10%,90)	3,553,972	5	0.9917	7	114
33*	(-, -,15%,10%,75)	3,574,117	5	0.9859	212	114

\*Inferior scenarios

An interactive stochastic goal programming formulation first developed. The model distinguishes itself from other models in this field in the modeling approach used. Decision makers' imprecise aspiration levels for the goals and retailers' imprecise demand are incorporated into the model using stochastic modeling approach, which is otherwise not possible by conventional mathematical programming methods.

An industrial case is used to demonstrate the feasibility of applying the proposed method to real distribution problems. Some realistic scenarios have been investigated based on DMs strategies. These strategies can be compared by determining the performance vector for each strategy. Consequently, the proposed method yields an efficient solution and overall degree of DMs satisfaction with the determined objective values. Accordingly, the proposed method is practically applicable for solving real-world multi-objective DPD problems in an uncertain environment.

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# **Chapter 11**

Freight Transportation and Logistics Management



## EVALUATION OF TURKEY'S FREIGHT TRANSPORTATION

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**Abstract** — *In this paper freight transportation of Turkey was evaluated according to transport modes. The transport modes analyzed include road, railway and waterway. The objective is to guide policy makers to correctly formulate strategies and make logical investment decisions about freight transportation system. There are freight transportation problems in Turkey because of unbalanced transport mode use resulting from lack of long-run strategic planning and accordingly incorrect investment decisions. The freight transportation of Turkey was evaluated by analyzing the past data. The freight transport data between years 1983 and 2005 for road and railway modes were used to obtain forecasts. The freight transport data of Turkey and European countries as of 2005 were analyzed based on cluster analysis. The suggestions were made in order to get a more balanced freight transportation system in a near future in Turkey.*

**Keywords** — *freight transportation, transport modes*

### INTRODUCTION

The volume of freight transportation has been growing significantly over the past few decades in Turkey. The amount of freight transport in year 2005 in million tones / km is about 3.56 times more than that of year 1983. When the distribution by transport modes is analyzed at the same time period, it can be seen that use of roads has increased 3.95 times, while use of railway has only increased 1.48 times.

The portion of highway, railway, waterway (maritime and inland waterways) and air transport differs in each country according to the geographical conditions, technologies, etc. of that country. In Turkey, highway use for both passenger and freight transportation has increased much more quickly than the other transport modes. As a result of this unbalanced development, the portion of highway has increased over 90%. During this development the number and freight capacities of transportation firms has also increased and idle capacities has formed, which results in fierce competition that makes an efficient and safe transportation difficult. In this medium, while traffic accidents increased, at the same time the physical structures of highways damaged quicker than expected because of the high ratio of heavy vehicle and excess loading of considerable amount of vehicles [1].

In order to maintain and improve the highway system in Turkey, billions of Turkish Liras are spent annually [5]. Although railway technology has shown a rapid improvement in the world, Turkey could not shown a parallel improvement in this area because of unbalanced financial distribution between transport modes. Also maritime is the transportation system that has the biggest portion (about 95%) in World's transportation system. It is 3.5 times more inexpensive than railway and 7 times more inexpensive than highway. Today, the burden of that situation on country's economy is discussed and studies to shift freight transport to other modes are conducted [1].

In the literature, studies were made to guide the transportation policy makers in their strategic decisions on transportation planning [2]-[4]. In this study freight transportation of Turkey was evaluated according to transport modes for the same objective as well.

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## EVALUATION

The freight transport data of Turkey by road, railway, maritime, and air transport modes between years 1983 and 2005 [6] are given in Table 1. Data do not include transport to or from foreign countries. The forecasting models are selected based on error measure MSE and diagnostic check. The forecasting method used for the road data is Box-Jenkin's ARIMA with parameters ( $p=0$ ,  $d=2$ ,  $q=1$ ). The forecasting method used for the railway data is Double Exponential Smoothing with smoothing constants  $\alpha=0.52$  and  $\beta=0.124$ . Because of the privatizations of Turkish Maritime Cargo Lines there are missing data in maritime transport, therefore forecasting could not be made for this mode. Also air transport was not forecasted because the portion of use of this mode is very low. As forecasts indicate, the increasing trends are expected to continue in the future (Figures 1 and 2). Therefore, energy use in freight transportation is also expected to increase. It is obvious that there is unbalanced transport mode use in Turkey in favor of road by 90.8% when total freight transport is considered by modes between years 1999 and 2003 (Figure 3). Road is the most energy consuming and environmentally harmful transport mode among all transport modes. Balancing mode share by railway and maritime for long-haul and by road for short-haul is the best way to achieve the most energy-efficient and environmentally sustainable way for freight transportation. Transportation planning and investment decisions should be made based on research on selection of optimal routes and optimal connections among modes according to a set of criteria such as cost, time, distance, safety, energy, and environment.

TABLE 1  
Turkey Freight Transport by Transport Modes (million tone-km) [6]

Years	Road	Railway	Maritime	Air Transport
1983	42189	6124	2934	57
1984	43878	7532	7719	63
1985	45634	7747	4504	59
1986	54018	7219	4682	64
1987	58832	7259	4541	79
1988	65459	8006	9454	88
1989	68239	7571	7152	95
1990	65710	7915	7234	107
1991	61969	7995	2780	76
1992	67704	8246	1756	102
1993	97843	8410	901	152
1994	95020	8215	587	198
1995	112515	8516	276	231
1996	135781	8914		240
1997	139789	9614		263
1998	152210	8376		274
1999	150974	8237	8200	286
2000	161552	9761	7900	310
2001	151421	7486	8100	285
2002	150912	7169	5738	275
2003	152163	8615	5400	276
2004	156853	9334		321
2005	166831	9078	6158	392



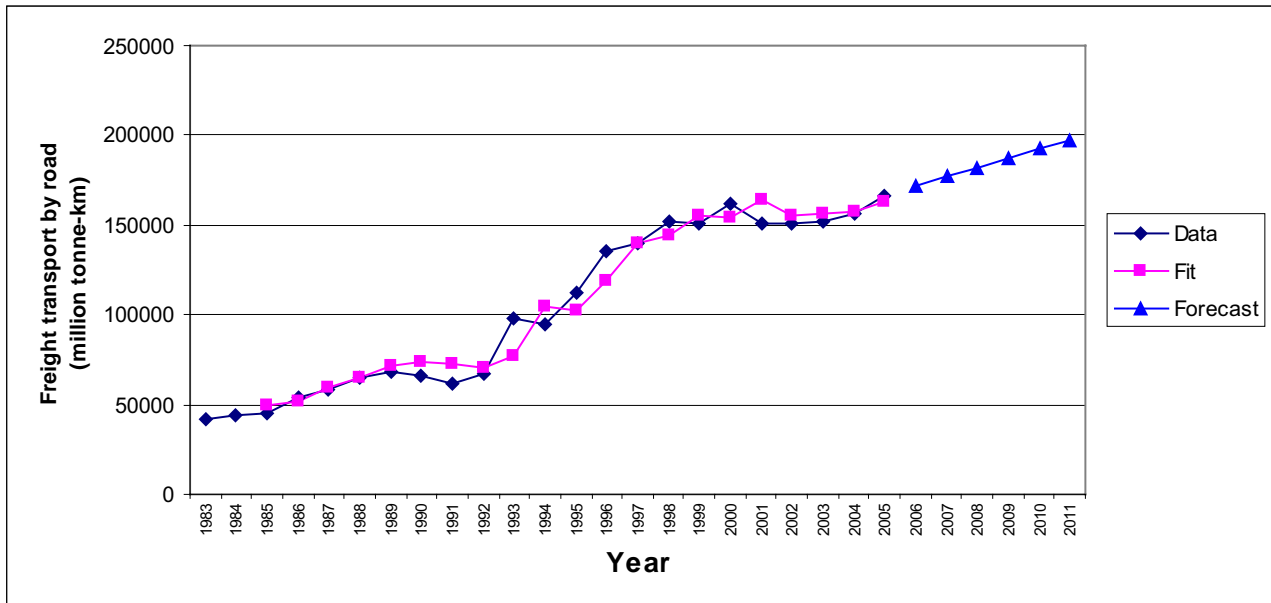


FIGURE. 1  
Forecasts for Freight Transport by Road

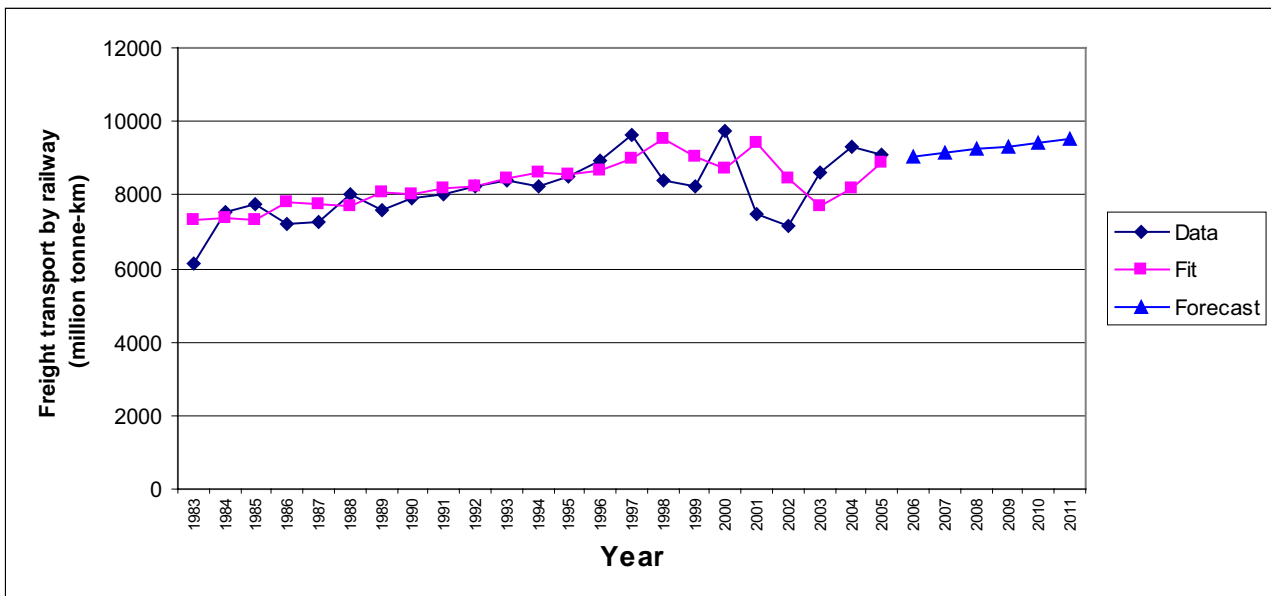


FIGURE. 2  
Forecasts for Freight Transport by Railway

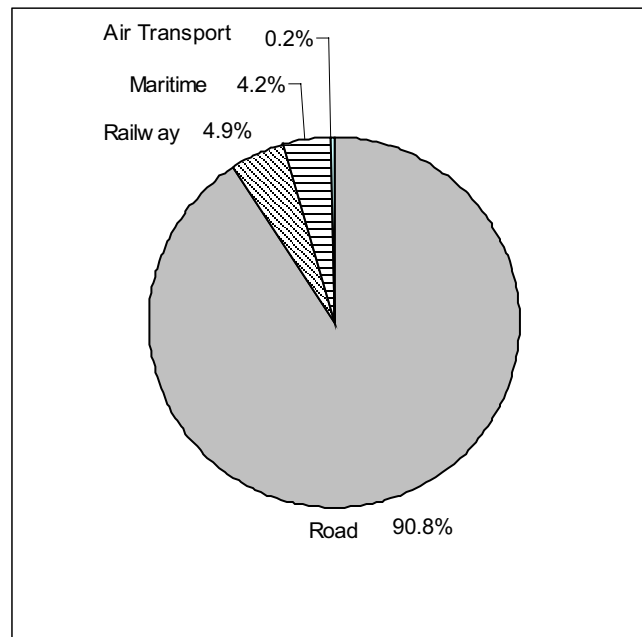


FIGURE. 3

Use of Modes for Total Freight Transport between 1999 and 2003

Freight transport data of European Countries for 2005 [6] are used to group countries into clusters such that each cluster is as homogeneous as possible with respect to the clustering variables which are freight transport by railway, road, and inland waterways. In cluster analysis we select Euclidean Distance as a measure of similarity and the hierarchical clustering technique with single-linkage method. Agglomerative algorithm used to develop clusters is the single-linkage method which is based on minimum distance. The data and the result of the analysis are given in Table 2. The cut shown by the dotted line in the dendrogram (Figure 4) gives the composition of a four-cluster solution. Cluster 1 contains Turkey, England, Italy, Spain, and France, all of which have high amount of freight transport. Among them Turkey is the one that use railway least. Cluster 2 contains Germany which has the highest amount of freight transport and balanced mode share. Cluster 3 contains Netherlands which has lower amount of freight transport and the largest share in using inland waterways. Cluster 4 contains the remaining countries which have lowest amounts of freight transport when compared with the countries in the other clusters.

TABLE 2

Freight Transport by Countries and Transport Modes in 2005 (billion tone-km)

Observation	Country	Railway	Road	Inland Waterways	Cluster
1	Turkey	9.1	166.8	0	1
2	England	22.1	154.4	0.2	1
3	Luxembourg	0.4	0.5	0.3	2
4	Greece	0.6	18	0	2
5	Ireland	0	14	0	2
6	Portugal	2.8	17.4	0	2
7	Germany	81.7	237.6	64.1	3
8	Denmark	2	11.1	0	2
9	Italy	23.1	171.6	0.1	1
10	Netherlands	4.3	31.8	42.2	4
11	Spain	11.6	166.4	0	1
12	Belgium	9.2	19.3	8.6	2
13	France	41.9	177.3	8.9	1
14	Switzerland	11.4	0	0	2
15	Norway	2.1	15.4	0	2

16	Austria	18	12.5	1.8	2
17	Sweden	13.1	34.7	0	2
18	Finland	9.7	27.8	0.1	2
19	Czech Republic	15.9	15.5	0.1	2
20	Slovak Republic	9.3	5.6	0.1	2
21	Hungary	9	11.4	2.1	2
22	Bulgaria	5.2	5.1	0.8	2
23	Croatia	3.1	4.4	0.1	2
24	Romania	14.9	19.4	8.4	2

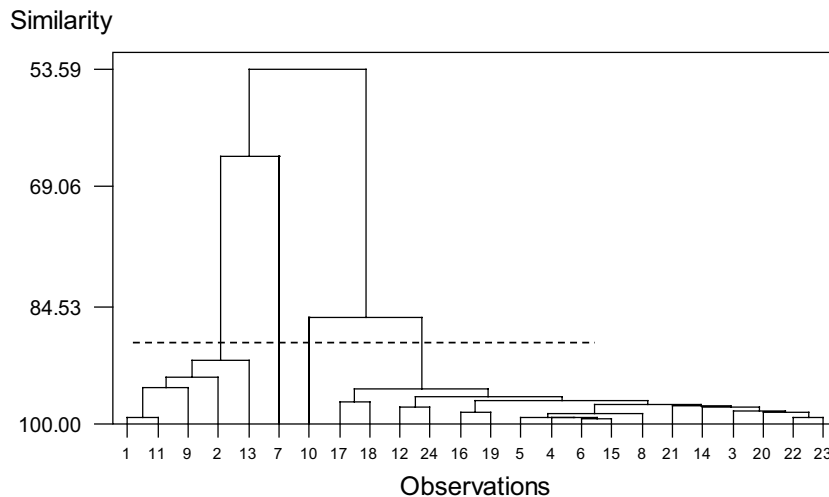


FIGURE. 4  
Dendrogram for Freight Transport Data

Policy makers in Turkey made investments for many years only in road transport and neglected railways. To obtain a balanced transportation system like Germany investments should be made not only roads but also railways and maritime. Turkey geographically is very suitable country to integrate all transport modes to develop a single and balanced system of transportation.

## CONCLUSION

There are freight transportation problems in Turkey because of unbalanced transport mode use resulting from lack of long-run strategic planning and accordingly incorrect investment decisions. In order to overcome the problems, all transport modes (road, railway, maritime, and air transport) should be integrated into a single system of transportation. The transport mode share should be balanced by using railway and maritime for long-haul and using road for short-haul in order to achieve the most energy-efficient and environmentally sustainable way for freight transportation. This requires detailed research on the selection of optimal routes and optimal connections among transport modes according to a set of criteria such as cost, time, distance, safety, energy, and environment. Policy makers should develop long-run strategic plans and make investment decisions for transportation using the results of that research in order to get a more balanced freight transportation system in a near future in Turkey.

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# SHORT SEA SHIPPING, INTERMODALITY AND PARAMETERS INFLUENCING PRICING POLICIES IN THE MEDITERRANEAN REGION: THE ITALIAN CONTEXT

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**Abstract** – The Short Sea Shipping (SSS) market is strongly diversified and segmented. The prices differ considerably among transport services of similar distance routes and/or similar demand characteristics. Therefore, the aim of the paper is to identify the factors influencing pricing policies of SSS operators and forwarders in the Mediterranean Sea, within the Italian perspective. The analysis of data collected, through telephone and face-to-face interviews with SSS operators, reveals that the variation in fuel and port costs plus the level of competitiveness of the markets influence deeply both cost structure and pricing policy of an intermodal transport service (with fuel costs being the most important element). For the forwarders the competitiveness of the market is indicated as the most important element affecting the final price of the forwarding service. However, validating the presented cost and pricing structures remains a challenge, since such data is quite sensitive and hence, not easy to obtain directly.

**Keywords:** Intermodality, Italian SSS operators and forwarders, Pricing of Transport Services, Short Sea Shipping, Transportation cost

## INTRODUCTION

Nowadays, Short Sea Shipping (henceforth SSS) represents one of the transport sectors on which the European policy focuses more and which is currently having a high priority in the European agenda. However, despite the environmental and safety advantages of SSS (CEU, 1999), this mode appears to be undermined by its inability to integrate in door-to-door chains, its unreliability in relation to time windows, its poor image and high average age of the European SSS fleet (EP, 1996; Systema, 1999, Paixão Casaca and Marlow, 2005).

In the most recent European orientation regarding SSS and intermodality (COM 2006/ 314), the current situation of transport industry in Europe is once more analyzed, the problems remaining are pointed out and hypothetical instruments for improving the transport systems in Europe are highlighted. Some of these problems are related not only with the strong diversification of the SSS market (type/size vessel, etc.), but also with its segmentation (many national and peripheral submarkets). As a result, the identification of the factors influencing pricing policies of the SSS intermodal transport is imperative to obtain a full development of the SSS in Europe. The growth of the SSS in Europe depends on its full integration in the transport (logistics) chain and consequently, in providing door-to-door services to customers (Paixão and Marlow, 2002) thus, the present study focused on both sea and inland leg (rail and road) of intermodal chains, within the scope of an integrated framework. Previous research on the subject is considered; findings are compared and validated against other relevant undertakings. More specifically, three EU funded research projects were analysed in detail; a) EMMA (European Marine Motorways); b) RECORDIT (REal COst Reduction of Door-to-door Intermodal Transport) and c) REALISE (REgional Action for Logistical Integration of Shipping across Europe). Additionally, international literature reports on SSS were reviewed, in particular the ones mentioning costs, factors influencing pricing policies and the integration of SSS in an intermodal chain. Dougall (2002) gathered costs of SSS services in specific routes and with particular vessels, while Musso and Marchese (2002) proposed a framework to identify the critical thresholds in land/sea distances and generalised costs in order to determine the competitiveness of the SSS. In Paixão and Marlow (2002), the complexity of a SSS intermodal chain is stressed and the obstacles to provide door-to-door services, when a sea-leg is introduced, are pointed out. Indeed, the authors mention that the success of intermodal transport is critical for the development of SSS. Within the scope, Brooks and Frost (2004) concluded that SSS has difficulties in

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meeting the service and price requirements of shippers. As already mentioned, the objective of this paper is to identify the factors influencing pricing policies of SSS operators and forwarders in the Mediterranean Sea, within the Italian perspective. The paper consists of five major parts. After the introduction, in the second chapter a theoretical framework of the study is presented. This chapter includes the analysis of the European SSS market - the Mediterranean region and brief summary of the main factors that may lead to price differentiation when setting the final price of a transport service. The third section describes the methodological framework used for the questionnaire development and content, the data collection method and the sample identification. Survey findings concerning the SSS operators and the forwarders interviews, their analysis and discussion are the scope of section forth. The conclusions regarding the major elements influencing the pricing policy of an intermodal transport service and the most important cost items in the cost structure of an intermodal service are presented in section 6.

## THEORETICAL FRAMEWORK

Depending on the criteria used, SSS can be seen as a mode between an extension or the complementary part of the deep-sea shipping and an integrated part of the intermodal transport services (Brooks and Frost, 2004). In this context, SSS operators can be divided into feeder operators, which usually do not provide hinterland transport services and regional operators, which typically offer door-to-door services (Systema, 1999). Furthermore, the SSS market can also be divided by geographical areas (North Sea, Mediterranean Sea, Atlantic Ocean, Baltic Sea, Black Sea and others) or according to the type of traffic (liquid, dry, unitized). There are many definitions for SSS, but an unambiguous one still missing (Musso and Marchese, 2002; Brooks and Frost, 2004). The paper uses the European Commission's (CEU, 1999) definition about SSS which has already mentioned. The scope of the paper is to analyse the Mediterranean Sea, a major field for SSS, playing a vital role in the movement of goods and passengers in Europe (Systema, 1999; ITMMA, 2007). Along with the North Sea, the Mediterranean Sea has the largest shares of SSS shipments in 2006, with 599 and 560 million tonnes, respectively (Amerini, 2008). In 2003, 68 SSS operators were operated in the Mediterranean region while 63 ports facilitated the SSS trade (Elliott, 2003). Furthermore, these SSS operators own the 39% of the EU SSS fleet (Malakasi, 2007). The average capacity of the Mediterranean fleet is 670 TEU, while the biggest ship carries about 3.428 TEU and the smallest vessel has a capacity of 126 TEU (Malakasi, 2007). According to Amerini (2008), *"the Mediterranean is the only sea region where goods in containers represents more than 16% of the total weight of short sea shipped goods"*. These figures are not solely due to the development of the SSS market, but are mainly the result of the faster increasing rate of trade between Asia and the Mediterranean area. Although still on a much lower scale compared to the trade volume between Asia and North Europe (Vaggelas, 2007). Nevertheless, it has to be highlighted that the total cargo transported in the Mediterranean region with the ability to be fully integrated into intermodal supply chains, Roll-on/Roll-off units and containers, is no more than 25% of the total cargo shipped (Amerini, 2008). This might be one of the reasons why SSS is facing problems in integrating in door-to-door chains.

Within the Mediterranean Sea, two submarkets can be distinguished: the Western area, which comprises by the West coast of Italy and the whole area to Gibraltar (which has experienced an amazing development since the middle 1990's); and the East area which includes all the ports and sea areas between Israel the east coast of Italy plus the island of Malta. This segmentation is based on the following three criteria:

1. Western Mediterranean market is a differentiated market regarding ports as it includes big hubs (e.g. Algeciras, Gioia Tauro, Taranto, Cagliari) and small ports.
2. Eastern Mediterranean market is characterised by equal sized and dynamic ports with few exceptions (Piraeus port).
3. Malta is situated in the middle of the previous categories.

When combining the origin and destination ports it is possible to conclude in the formation of 589 routes in the Mediterranean Sea (Malakasi, 2007). In 2003, the largest container flows were observed between Spain and Italy, 420.000 TEUs, and among Italy and Greece, 319.000 TEUs (Waals, 2005). In 2006 Italy was considered the major contributor to the SSS freight flows on the Mediterranean Sea, not only with other EU ports but also with other Mediterranean countries such as Croatia, Bosnia-Herzegovina, Montenegro, Albania, Syria, Lebanon, Occupied Palestinian Territory, Libya, Tunisia, Algeria, Gibraltar, Morocco, Egypt, Israel and Turkey (Amerini, 2008). Indeed, Italian ports (e.g. Genoa and La Spezia) play a leading role in the SSS Mediterranean market mainly due to their particular geographical position (Malakasi, 2007).

The full development of the SSS in Europe depends not only on its physical integration in the supply chain, but also on the competitiveness of the intermodal service in terms of cost, timing, flexibility, reliability,

risk of damage, type of goods and frequency (Vassallo et al., 2004). In this context, Tsamboulas and Kapros (2000) considered the cost of the intermodal transport service as the most important criterion affecting the decision-making process of intermodal supply chain. Several studies (Zachcial, 2001; Paixão and Marlow, 2002; Nitsopoulos and Psaraftis, 2007) support that ports efficiency and port charges are considered as barriers when choosing an intermodal transport chain with the use of SSS. The latter is considered an obstacle not only due to the high tariff, but also due to the wide variability between ports, without justification (Lindsay, 1998). For example, in the Gioia Tauro–Manchester intermodal corridor, in particular in the Gioia Tauro–Genova leg, it was observed that the port charges (excluding transshipment) were between 25–30% of the total SSS cost (Vassallo et al., 2004). On the contrary, Saurí (2006) assumed that the ship capacity has a bigger impact in the total cost of the supply chain rather than the port productivity. He argues that the competitiveness of SSS basically relies on the economies of scale in deploying larger vessels (Saurí, 2006), as port operational costs do not increase proportionally with the ship capacity and therefore, the unit cost falls as ship size increases (Sys et al, 2008). Since the costs of the intermodal transport chain are one of the most important factors influencing the choice of the transport mode, the general cost structure of an intermodal transport service was analysed, considering both EU projects RECORDIT (Baccelli et al., 2001b) and Realise (Vassallo et al., 2004). When examining the cost structure of the three corridors, selected by RECORDIT: Genoa–Basel; Basel–Rotterdam; Rotterdam–Manchester, it can be noticed that the SSS integration in the complete logistics supply chain has not been analysed sufficiently. However, in REALISE project the corridors that have been selected (Gioia Tauro–Manchester; Athens–Gothenburg; Lisbon–Rostock; Le Havre–Gdansk or Helsinki) are more representative of the actual freight flows in Europe and therefore, the comparisons between multimodal and all-road solutions provide “*valuable insights in the integration of different freight transport modes in Europe*” (Lloyd, 2003).

Moreover, it has been observed that intermodal transport costs are not that closely related to intermodal transport prices and that even these prices differ considerably among transport services of similar distance routes and/or similar demand characteristics. In fact, it is known that the variation of products and customers creates opportunities for price differentiation and the extraction of user surplus for some customers. In this context, Baccelli et al. (2001a) observed that the opportunity for differentiation between customers is reduced if there are active operators in the market willing to provide the service at marginal cost, given that the extent of price differentiation is in direct relation with the level of competition in the intermodal market. The same author concluded that in the end, the forces affecting the final price of the service are complex, interdependent, difficult to survey and often difficult to measure accurately (Baccelli et al., 2001a).

## RESEARCH METHODOLOGY

The data for this study was collected through a semi-structured questionnaire via telephone and face-to-face interviews. The latter were used to verify and support interpretation of the telephone interviews. In total, 15 SSS operator interviews and 17 forwarder interviews constitute the primary data of the following analysis. The used semi-structured questionnaire, the data collection and the sample selection procedures are described herewith.

### Semi-structured questionnaire development and content

The semi-structured questionnaire was developed in order to understand how the operators and forwarders set the prices of the transport services and which factors (not costs) could influence more the final price. Furthermore, the questionnaire focused on market structures and services offered. Additionally, the survey aimed to identify the cost elements of an intermodal transport service and to realize their relative importance in the total cost structure. The basic structure of the questionnaire was similar for SSS operators and forwarders, but not the same as their business activity and structure differs. The operators were asked to specify the type of service they offer (door-to-door, port-to-port or both). If the operators provide door-to-door service, they were asked, if they outsource the hinterland part and if they do so, what kind of contract or relationship they have with the third party. In addition, the operators were asked which elements guide them to choose between providing door-to-door or/and port-to-port services and if they have specific routes where one, of the two services, is predominant. Secondly, the operators and forwarders were asked to provide information concerning the cost and the price structure of the service. Additionally, just for the forwarders, two questions were added, concerning the decision-making process about the mode of transport and the transport service providers.

### **Data collection and sample selection**

A brief field survey was made to define both the market structure and the operators working in the SSS Mediterranean area, in particular the ones specialized in Roll-on/Roll-off (henceforth Ro-Ro) or container transport. The webpages of SSS promotion centre of Italy (<http://www.shortsea.it>), Greece (<http://www.shortsea.gr>) and France (<http://www.shortsea.fr>) were used to define the operators providing SSS in the Mediterranean area. The research was focused mainly on the Italian SSS operators which play a leading role in the Mediterranean SSS market. Hence, a convenience sample was used in the survey.

In total, 22 out of 48 recognised SSS operators were contacted in order to participate in the research. The response rate was 68.1%, corresponding to 15 interviewed operators out of which twelve SSS operators were interviewed through a telephone interview in November 2007 and three SSS operators were interviewed through a face-to-face interview in April 2008. The sample of forwarders was identified just in the area of the port of Genoa, and therefore also in this case the focus was essentially on the Italian market. The operators' contact details were taken from the Genoese Freight Forwarder Association webpage (<http://www.spediporto-genova.com>). The initial sample of companies constitutes 17% of the total number of operators in Genoa.

The field research completed in phases: a) a first contact where 33 companies were contacted to ask their availability for the research and b) a face-to-face interview where 17 operators were interviewed (formatting a response rate of 51%). The interviews were conducted during May 2008. A preliminary contact with the companies was taken through telephone call, in March and April 2008 and the face-to-face interviews were conducted in May 2008.

## **SURVEY FINDINGS AND DISCUSSION**

### **SSS operator interviews (including telephone and face-to-face interviews)**

The majority of the SSS operators provide either container transport (11 operators) or Ro-Ro services (3 operators). Only one SSS operator provides both services. Most of the operators (14 out of 15) provide door-to-door service and only one Ro-Ro operator had a port-to-port line service. The operators offering door-to-door service cover the inland leg either with their own assets or by subcontracting the inland transport services. Based on the results it appears that the operators offering door-to-door services in most cases do not have their own means for offering the land transport and they are mostly cooperating with third parties for the hinterland transport. This could be due to the need of the customers for a complete service from the origin to destination. In general, SSS operators have considerably midterm contracts (essentially for one year) with both rail and/or road transport providers. Regarding the two operators that have internal assets for hinterland transports their focus is on specific routes and/or loading units.

Based on the operators' answers (13 out of 15), there are four main decisive factors that the operators consider before deciding to provide a door-to-door or a port-to-port service: the destination of the freight, the type of goods, the loading unit and the competitiveness of the market. The destination of the goods seems to be the leading factor, as it was recognised by the majority of the SSS operators (67%), followed by the type of goods, the loading unit and the market competitiveness. Additionally, the respondents were asked to rank the three main costs of a transport service, from the most (1) to the less (3) important item. Seven SSS operators identified as more relevant fuel costs and five operators pointed out charter rate or ownership (this item is related to either with the cost of hiring vessels or with costs of ownership). The item "port costs" such as operation and fees has as well high relevance on the final price only when operators own the vessels or have a time charter contract with the shipowner and therefore, have to pay all voyage related costs. "Personnel costs" is considered an important item only when the operator owns the vessel and as a result, has to bear all transport related costs. Hinterland transportation, maintenance and SSS supplier markets costs seemed to have less importance on the total transport expenses.

Concerning the elements influencing the final price, the fuel cost and market competitiveness were identified eight times by the operators as two of the main elements in the variation of the annual price followed by seasonality (high peaks and low peaks related to the business trends). Additionally, the operators considered final destination, port costs, type of goods, nature of the customer and currency as other elements that can lead to price differentiation. Furthermore, all three interviewed operators indicated the specificity of each market and the peculiar characteristics of the customer and/or shipment as important factors affecting their pricing strategy.



Finally, the operators were asked to declare the break-even point of loading capacity for not providing the service. Based on the results there is no minimum size of transshipment that allows the operator to cancel the scheduled service, as these operators admitted that have to offer the liner services despite of the demand.

In order to compare the results of this paper to other studies, the ranking of the main cost items was replaced with weighted values. Mainly all the operators consider charter rate or ownership along with fuel costs as the most important items in the final cost. The port costs were in the third place. These results were compared with the outcomes obtained from the EU project entitled REALISE (where the cost structure of some intermodal transport routes in Europe were described). Depreciation of the ships was considered the most important cost item, in 3 out of the 4 routes selected from the REALISE report. Here, the interviewees pointed out charter rate or ownership (where depreciation costs are included) as the second most significant cost. The second and third higher cost items identified by REALISE were fuel and port costs, respectively. The latter item was recognized as well by the interviewees as the third main cost. The difference is that fuel cost was mentioned in these interviews as the one having the largest impact in the total transport costs. This fact might be related with the instability of oil prices in recent years. Indeed, back in 2003/2004 when data and interviews for REALISE were collected the oil prices were not this high.

### Forwarder interviews

Nearly all forwarders (15 out of 17) provide both door-to-door and port-to-port services depending on the customers' needs. From the remaining two forwarders one provides only port-to-port services and the other one door-to-door services and door-to-port and port-to-door services. The general tendency for the forwarders is to offer a complete service until the final destination. However, there are some exceptions that compel the operators to limit their service to the port. This happens when it is considered relatively dangerous or too complicated to ship freight from the inland origin to the inland destination. The activity structure of a forwarding company is generally not dealing with the own provision of transport service, but usually the forwarder is contracting the transport service with rail or truck companies. The forwarders have normally following contracts with the clients and operators: (a) Commercial agreements with the clients, which are stipulated when the customer require the service (with the exception of big clients that prefer to settle an annual contract), (b) Contracts with road transport companies annually or monthly (from three to six months). Only five forwarders declared to have occasional contractual relationships with trucking companies, (c) Contracts with rail transport companies usually in an annual base, for the forwarders that use more rail transport. Otherwise the contracts are stipulated one at a time and (d) Contracts with maritime transport companies (often occasional). The forwarders declared to contract the service according to their needs, without having a fixed agreement.

Regarding the ranking of the three main costs pointed out by the forwarding companies, these are: box rates, hinterland transportation costs (as forwarders have to contract transport companies) and lastly, loading/unloading costs. Here the "administration costs" item can also include documentation and/or packaging expenses.

When looking the elements influencing the final price of service, the competitiveness of the market was elected as the main element influencing the price. The special services was selected as the second more relevant item, with this terminology the operators referred to several additional and particular services that the client may ask, e.g. extra fast deliveries or custom clearance and return of empty containers. Additionally, some forwarders considered the nature of customer, type of goods and size of shipment as relevant factors affecting the final price. Destination and seasonality are also mentioned as elements that can lead to price differentiation, but none of the forwarders indicated them as the most significant ones.

Based on the received answers the selection of the providers of road and rail transport is mainly done by the forwarders. It seems that the decision is made by the forwarder himself (indicated by 16 out of 17), and just in one case the sender and consignor choose the transport providers. Furthermore, the forwarder is making the final decision when the combination of the different modes of transport has to be settled. In most of the cases, in 9 out of 17 companies, the forwarder makes the decision alone, and in the remaining cases the choice is agreed among the involved parties (receiver, sender and forwarder). Finally, the forwarders (like the operators) were asked if they have a minimum loading freight volume for providing the service; in this case this is not due to any liner service, but only to company policy. All the operators declared that the only service that they did not provide was the parcel delivery.

## Discussion

Based on the information gathered during the interviews, a relationship between major elements influencing the price, by operators and forwarders, and the importance of cost items in their cost functions was established. All the elements influencing the price of the transport service provide an opportunity for the intermodal operator to discriminate between customers and utilize the differences in their willingness to pay. For example, the market power of the customer increases with the size of the shipment and in this case, price reductions can be negotiated with the operator. The long term relations or occasional contracts are usually elements of differentiations among customers. In Figure 1, the relationship between different elements influencing price and cost defined by shipping operators are shown.

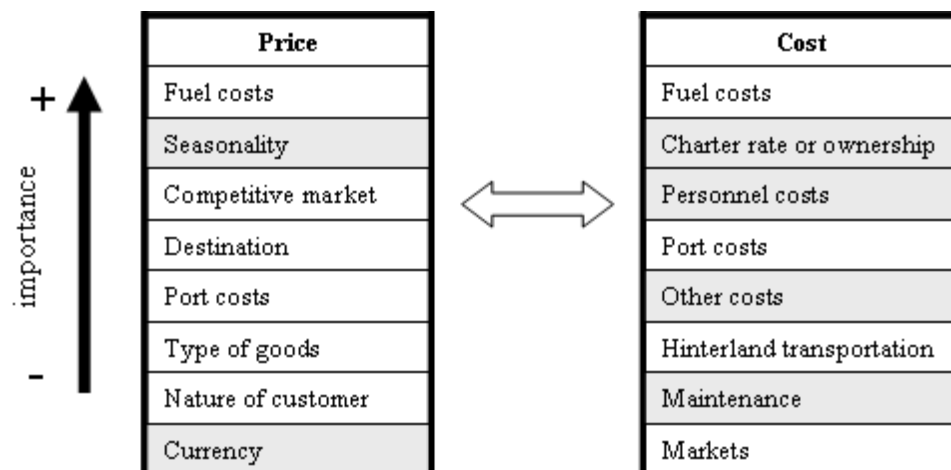


FIGURE 1

The relationship between different elements influencing price and cost defined by shipping operators.

In order to define the unstable factors influencing pricing policies for SSS services it is necessary to remove all the stable and residual elements from the relationship (marked as shaded grey colour in figure 2). Thus, personnel costs, charter rate or ownership and maintenance are removed, as they are assumed to be stable during the one year period. Concerning seasonality, operators assumed having the necessary experience based on previous periods. Furthermore, currency is removed, because all the money transactions in the Mediterranean area are made in euros. Additionally, other costs are removed as well, due to their residual nature. When analysing the remaining relationship defined by SSS operators the following considerations can be outlined: (a) The fuel is considered one of the most important elements and the operators can not influence it, since the fuel price fluctuates according to the world fuel market, (b) The cost of an intermodal service with a SSS leg and its final price is understood as closely dependent on the final destination and the inland transport modes used. This is related with the fact that there are destinations, where the door-to-door service is easier and cheaper to organise, (c) The role of the port costs is regarded to be a critical element when defining the final price of the service and also when the operator is defining its business strategy. According to the results of EMMA project (Lindsay, 1998) port charges vary widely without apparent justification and they can be reduced by effective negotiations and (d) The role of the market in the SSS sector, or rather the competition within the operators following the market dynamics, is viewed by the operators as an important element when defining their pricing strategy regarding each SSS service.

Regarding the forwarders results, the relationship between major elements influencing the price defined by forwarders and the importance of cost items in the cost function can be seen in the Figure 2. When comparing both price/cost relationships (from SSS operators and forwarders) some differences can already be pointed out (*see figure 1 and 2*). In the beginning the stable and residual factors were removed the relationship as in the previous relationship (marked as shaded grey colour in figure 2). Consequently, the seasonality, box rates, personnel costs and administration costs were removed, as forwarders assumed to be stable during the one year period. Fuel costs were also removed, since it was indicated by only one forwarder. Moreover, this cost is usually included in the price that the forwarders need to pay to transport providers.

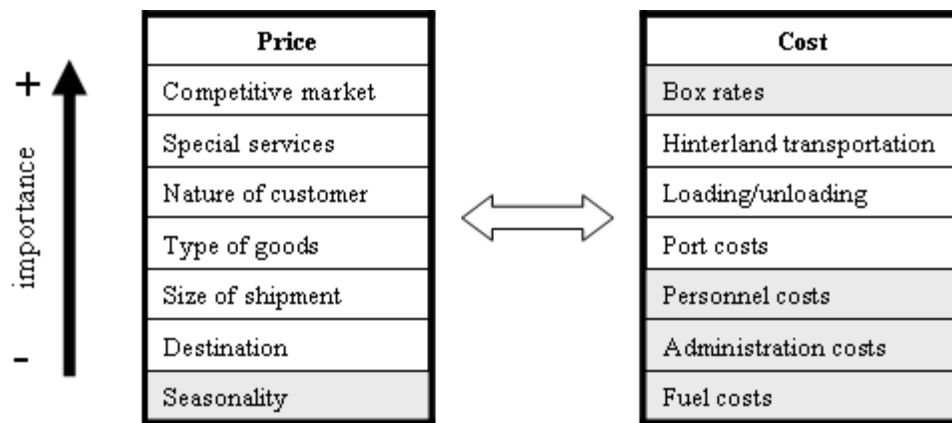


FIGURE 2

The relationship between different elements influencing price and cost defined by forwarders.

When analysing the remaining relationship defined by SSS forwarders the following considerations can be outlined: (a) The competition within the forwarders is indicated as the most important element affecting the final price of the service and therefore, the desired profit margins; (b) Other important elements affecting the price are those related to price differentiation. However, the competition between forwarders is also related here, since it is affecting the opportunity for differentiation between the variation of products and customers. As already stated in the literature review, the extent of price differentiation is in direct relation with the level of competition in the intermodal market: (c) The cost of hinterland transportation is largely affecting the total transport service costs and (d) Port charges and loading/unloading represent important items also in the cost structure of a forwarding company. These are all indirect costs that the operators have to consider when offering a door-to-door service and that have a relevant role in the election of the transport supply chain.

## CONCLUSION

The paper contributes to the discussion regarding the pricing scheme and the cost structure of the intermodal transport with a SSS leg. The analysis of collected data assists the understanding of the revealed parameters influencing both price and cost. These evidences could lead to further lines of research.

Regarding the factors influencing the operators' pricing policies, fuel was considered the most important. Indeed, this item was considered the principal cause for annual price variations, followed by charter rate or ownership, related either with charges for hiring a ship or depreciation costs, when SSS operators own the vessels. Even though these two costs are not exactly the same and therefore, are influenced by different elements, it is assumed here that they are both high fixed costs, from these operators' point of view. It is also clear that the market adds dynamics over the price strategy for every operator and forwarder. The SSS market is highly competitive with a wide variety of operators on different routes. In this context, the entry to the road transport market is even easier than to maritime market since the trucks are cheaper to run and operate than ships. The market for rail operators is at the moment more stable as it is an oligopolistic market. However, due to the complexity of self-organised systems, validating these cost functions accurately presents a great challenge. Regarding the cost items, the analysis of data collected revealed that the variation in fuel and port costs plus the level of competitiveness of the markets influence deeply the cost of an intermodal transport service. The total transport cost is also affected by changes in the hinterland transport costs. For the forwarders the origin and destination appeared to be the main items influencing the final cost of service whereas for the majority of operators, the origin and the destination of the goods influence the choice of providing the service (door-to-door or port-to-port). It has also been referred in other studies (e.g. Vassalo et al., 2004) that there are difficulties to obtain data concerning cost items and especially unit costs. According to REALISE project this is on the one hand due to the difficulties by extracting unit costs out of balance sheets of operators and forwarders and on the other hand due to the unwillingness of the managers to provide sensitive data by interview. The research undertaken may be considered as a pilot effort to be extended in the future, in order to include more surveys (possibly containing quantitative data) and in-depth analysis of case studies, in order to produce a concrete form of the cost structure and pricing scheme structure.

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# RELEVANT STRATEGIC CRITERIA WHEN CHOOSING A CONTAINER PORT - THE CASE OF THE PORT OF GENOA

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**Abstract** — Ports act as interfaces between different transport modes. Therefore, it is important to determine the key factors that guide the users in choosing a specific port. The purpose of this paper is to identify which are the main factors and criteria influencing the decision of freight forwarders in choosing a port. To meet this purpose a methodology has been developed which is based on qualitative analysis. First a review of the relevant literature reveals a range of factors affecting such decision. The theoretical step is complemented by a survey method applied to the Port of Genoa. A questionnaire has been developed and submitted to a sample of forwarders. The data collected was analysed using the Factor Analysis method. The findings of this research show that the main elements affecting the decision of port choice are: connectivity of the port, cost and port productivity, electronic information and logistics of the container.

**Keywords** — Container Port, Freight Forwarders, Hinterland Connections, Port Choice, Port Performance

## 1. INTRODUCTION

Globalisation and increased competition are two of the main forces currently shaping the development of the port sector. The novelty in this global economy is the degree of interdependence between actors and the possibility to choose worldwide the inputs, intermediate or finished products and services. This leads to increased competition in every step of the logistics chain. There is, therefore, an international decomposition of productive processes and a global delocalization of manufacturing. These trends in manufacturing and logistics require more transport and more often, i.e., transport intensive.

Ports act as interfaces between different actors, such as road, rail, inland waterway, maritime transport and logistics operators. In a competitive port environment it is important to determine the key factors that guide the users in choosing a specific port. The knowledge of these factors can help a port improving its market share and growth. Efficiency gains, which are generated within the container port, will have a direct impact on the competitive advantage of its users and affect the economic potential of both origin and destination hinterlands.

The purpose of this paper is to identify which are the main factors and criteria influencing the freight forwarders decision of choosing a port. When analyzing these factors it is relevant bearing in mind that the choices of the economic actors are based on several and different elements. Such elements are related not only to the technical characteristics of the port, but also and increasingly more to hinterland and logistic services offered.

The choice of the Port of Genoa as a case study was mainly due to its relevance in the Mediterranean maritime scenario. Genoa is one of the main ports in the Southern European Range and given its favourable position in the north of the Mediterranean Sea constitutes a strategic node for the freight flows towards Central Europe. In 2007 Genoa was the 7<sup>th</sup> biggest port in the Mediterranean range and the 15<sup>th</sup> biggest in Europe according to throughput. It moved 1855 Mln teu and was the 2<sup>nd</sup> Italian port after the transshipment port of Gioia Tauro (webpage of Port of Rotterdam).

The Port of Genoa also plays a relevant role in the current European policies, with the TEN-T project identifying the Rotterdam-Genoa rail freight corridor as one of the most urgent action for promoting a more sustainable modal split of the freight transport in the European Union.

The port faces some challenges to its future growth. On one hand, port location constitutes a problem in relation to hinterland connections since the city of Genoa is surrounded by the Apennines Mountains and

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effective rail and road connections to the prosperous Northern Italy and Central Europe are still missing. On the other hand, the lack of space for the port's expansion is a major issue that limits its development.

According to Midoro, Ferrari and Parola (2007) potential growth in port throughput is strictly related to the improvements in port infrastructure for logistics activities, accessibility to port area, administrative procedures and port operations efficiency.

The choice of interviewing freight forwarders allows us to obtain a broad and clear idea of the current situation of the port, since these operators have broad perspective of the transport and logistic chain.

To meet this paper's purpose a methodology based on qualitative analysis has been developed. First, a detailed review of the literature on port choice reveals a considerable range of factors affecting the decision of choosing a port. Second, based on the literature review a set of elements was considered and a 5 point Likert scale questionnaire was elaborated (see Annex I). Third, this questionnaire was submitted to a sample of 33 companies, with a positive response from 26 freight forwarders, currently operating in the port of Genoa. The interviewed were asked to rank each of elements in a scale from 1 (not relevant) to 5 (very relevant). The data collected was analysed using the Factor Analysis (FA) method.

The results of the FA show that in the case of Genoa the factors affecting the choice of the port can be distinguished in 4 Factors: (1) Connectivity of the port, (2) Cost and Port Productivity, (3) Electronic information and (4) Logistics of the container. The findings of our mathematical approach lead us to confirm what has been argued in the literature review and also in the general understanding of the operators dealing with ports problems on a daily base.

The remainder of the paper is organised as follows. In the next section a description of the methodology used. In section three, a detailed review is done on the existing literature on factors influencing port choice. Section four presents the questionnaire design and responses while section five handles the descriptive and statistical analysis, the FA and the results. The final section draws some conclusions and comments on future research.

## 2. METHODOLOGY

The methodology used in this research is based on qualitative analysis and consists of four steps that build on the previous one:

1. Review of the literature on the existing academic research on the topic of port choice and outline the major findings;
2. Develop a questionnaire using the information from the previous step. We opted for a 5 point Likert scale questionnaire, ranging from 1 (not relevant) to 5 (very relevant). Submit the questionnaire to a sample of freight forwarding companies operating in the port of Genoa. The interviewed were asked to rank each of elements.
3. The data collected through this survey was analysed using the FA method.
4. Validate findings of this case study against previous academic research.

As mentioned above, the analysis of the relevant criteria for the port choice has been done using a factor analysis approach. FA is a multivariate statistic data reduction technique that aims to explain the common variance in a number of variables within a single variable called factor. The main purpose of FA is to generate groups of correlated elements taken from the initial data set and with this process it is possible to capture latent or not clearly observed dimensions (Stevens, 1986). In other words, if two variables show a strong correlation with the same factor, some of the correlation between the two variables is explained by their common factor (Dillon and Goldstein, 1984).

This method allows the substitution of the original variables with a lower number of factors, not interdependent among them, obtained with a linear transformation of the original ones. Following this process it is possible to reduce the number of variables that explain and describe a phenomenon.

## 3. LITERATURE REVIEW ON PORT CHOICE

Several studies, such as Slack (1985), D'Este and Meyric (1992), Dalenberg, Daley and Murphy (1988, 1989, 1991, 1992a, 1992b, 1994), Lirn et al. (2003) and Song and Yeo (2004) rely on surveys of port users to get information on factors influencing port choice.

Slack (1985) established that the number of voyages and the inland freight rates were most important factor concerning port choice. Relevant port characteristics included the connection to inland transport

services and availability of container facilities. The author concluded that "the choice of port depended more on the price and quality of service offered by land and ocean carriers than on the attributes of ports themselves."

D'Este and Meyric (1992), conclude that in most cases the port is just another factor the shipper evaluates in the selection of a carrier. The authors suggested that as carriers increased their scale of operations and shippers began soliciting prices for door-to-door service rather than individual segments, the port selection shifted from the shipper to the carrier. The authors concluded that in the selection of a port, decision makers seem to value service characteristics more highly than price characteristics.

Dalenberg, Daley and Murphy have done considerable research on factors used by various parties in their selection of international water ports, namely the viewpoints of worldwide water ports (1988), water carriers (1989), U.S.-based international shippers (1991, 1992b), international freight forwarders (1992a), and purchasing managers (1994). The authors gather the perspectives of the various parties, since they represent different interests and roles in global logistics. Yet, analysis of the relative importance of the selection factors shows a high degree of similarity between shippers and carriers.

In order to analyse liners transshipment port selection Lirn *et al.* (2004) applied the Analytical Hierarchy Process (AHP) method to 47 selected relevant service attributes established from a literature review. The authors then conducted two rounds of Delphi surveys involving experts in industry and academia. This process allowed categorizing these attributes into 4 main service criteria: physical and technical infrastructure, geographical location, management and administration and terminal cost. These are further subdivided into 12 sub-categories.

The results of the AHP analysis targeting 20 carriers and 20 port operators shows that both container carriers and port service providers have a similar perception about the most important service attributes for port selection; however, the weights among the sub-criteria reveal some differences between the two survey groups. Through the AHP survey the authors revealed that the five services attributes such as handling cost, proximity to main navigation routes, proximity to import/export areas, infrastructure condition, and feeder network are the most important service attributes of transshipment ports.

Song and Yeo (2004) aimed at identifying the factors contributing to the overall competitiveness of Chinese main ports. Their focus is on elements concerning geographical location as well as logistics and operational services provided by the ports. A survey was conducted to a sample of 180 professionals including ship-owners, shipping company executives, shippers, terminal operators and academics and researchers. This resulted in a list of 73 factors for port competitiveness. Then on a second step, the opinion of 70 specialists, narrowed this list down to the five most important criteria for the port competitiveness, namely cargo volume, port facility, port location, service level and port expenses.

Similarly to Lirn *et al.*, an AHP method was used to evaluate the priorities among the identified factors, concluding that the location factor plays the most significant role for a port's competitiveness. The authors argue port facilities and services can be improved upon, whereas geographical location and cargo volume are considered to be taken as granted.

An alternative approach to research the factors influencing port choice is to base the analysis on the observed port decisions. Examples in literature of statistical analysis of a targeted set of shipments are Malchow and Kanifani, 2001 and 2004, and Tiwari *et al.*, 2003. Both these studies gather data on import shipment choices for a given point in time, select commodities and then estimate a multinomial logit model to identify the effect of certain factors on the port choice.

To explain the selection of a port for four types of cargo exported from the U.S Malchow and Kanafani (2001) used a multinomial logit model. The authors' intention was to test the significance of distance (ocean and inland), frequency of sailings, and average size of vessels sailing along a route. They conclude that ocean distance and inland distance have significant influence on export port selection but sailing frequency and vessel capacity are not considered as important criteria.

In 2004 Malchow and Knanfani applied once again a discrete choice model to the assignment of shipments to vessels/ports. The purpose was to evaluate competition among U.S. export ports. The authors assumed that shippers' preference for a port is established by choosing a carrier providing a service through that port. Findings reveal that geographic location, port characteristics and characteristics of vessel schedules are critical port selection factors, being port location the most significant of the three factors.

Tiwari *et al.* (2003) use data obtained from a survey of shippers of containerised cargo in China in 1998 to model the port choice behaviour of shippers using a discrete choice model. The authors conclude that the most important factors are the distance of the shipper from port, distance to destination (in case of exports), distance

from origin (in case of imports), port congestion, and shipping line's fleet size. The authors also analyse the elasticities of changes in these variables and their impact on the market share of shipping line–port combinations.

Blonigen and Wilson (2006) examine port choices of U.S. import shipments for the period 1991-2003 using a model of bilateral trades. This model was developed to capture factors such as locations of the traders, total transportation costs on the links and nodes that connect the traders including the ocean rate, the port costs, and the internal transportation rate. On a following step the impacts of each of these factors on the ocean port choices made by shippers for imports into the United States (US) are tested. The study findings stress that distance and transport prices are very significant factors with quite elastic responses by shipments. It is interesting to note the unlike previous studies, the authors conclude that the efficiency of an individual port has a significant role in determining its share of activity.

Based on the literature review a set of elements was considered and a 5 point Likert scale questionnaire was elaborated and submitted to a sample of freight forwarding companies currently operating in the port of Genoa. The next section explains the survey conducted used in this research.

#### 4. SURVEY

The survey was conducted through a structured questionnaire that was submitted to freight forwarding companies in the port of Genoa. The contacts were taken from the Genoese Freight Forwarder Association ([www.spediporto-genova.com](http://www.spediporto-genova.com)), which the total number of associated freight forwarders corresponds to 191 in 2008. For the purpose of our research we decided to contact the companies with bigger dimensions that represent a bigger share of the market. So, the sample selection was done according to the higher level of annual sales, to the number of employees and to the legal company form, as indications of the dimension of the company. The field work was comprised of two phases: a telephone contact followed by a face-to-face interview. A first contact with the companies was taken through telephone call, in March and April 2008. During this first step we explained them the purpose of our research and they were asked for the availability to a face-to-face interview to be conducted in May 2008.

In the first phase a sample of 33 companies, which represents 17% of the total number of freight forwarders operating in the port of Genoa, were contacted. 28 out of the 33 declared their availability in participating in the study. However, during the second phase of the field work 2 other companies declared their impossibility to take part. The final sample of forwarders was composed by 26 operators, which means a 78% response rate. The interviews were conducted during May 2008 and the meetings took place at the freight forwarders offices. The vast majority of the offices have the same location, in a specific area of the city of Genoa, very close to the port access. It is relevant to stress that the interviewed were the general managers and chairs of the companies. This allowed us the possibility of gathering more accurate and precise information.

During the interviews, the respondents were asked to answer the questionnaire, in annex, with the support of the interviewer. The questionnaire was mainly divided in two parts: the first concerns some general information about the company, while on the second part the interviewed were asked to express their opinion on 39 variables, ie, elements potentially affecting port choice; and rank them in a 5 point Likert scale, from 1 that stands for “not relevant” to 5 “very relevant”.

The data collected through this survey was analysed using the FA method. FA has shown to be a useful approach when investigating port competitiveness among ports and choice criteria affecting port users (e.g., Haezendonck 2001 and Gardner, Lalwani and Mangan, 2002).

In this paper on a matrix of correlations was performed and the FA was conducted in exploratory form. An iterated principal component FA was conducted and in the first iteration was taken into consideration just the factors with an eigenvalue greater than one, obtaining 11 factors.

Considering the high number of factors obtained from the first step, it was decided to proceed with the identification of a more appropriate number of factors. To identify factors, the total variance explained and the scree plot were considered. In the scree plot the shape of the curve was analysed; a shape fall in the eigenvalues curve often suggests that the factors on the upper side of the fall are the ones that should be maintained. In the FA a Varimax (orthogonal) rotation was used and as well as SPSS software to process the data.



## 5. ANALYSIS OF THE RESULTS

An important clarification that needs to be made is related to the number of variables and the total observations of the survey. The companies interviewed were 26, while the initial numbers of variables were 39, later reduced to 31 as explained below. It is possible to argue that the number of observations is too small when compared to the number of variables; this aspect has to be considered when analysing the final results of the FA.

The reduction from 39 to 31 variables was also due to the low relevance of some of them; the process of selection of the relevant variables was conducted looking at the Component Score Coefficient Matrix and excluding the ones that scored very low in all the four factors.

The companies in the sample are located in a specific area of the city of Genoa, close to the container port. Due to historical and economical reasons the forwarding activity is traditionally located very close to port facilities; in fact the managerial offices are located within 1 km of the SECH container terminal and within 15 km of the Voltri container terminal. The distance between the port and the offices is an important criteria for choosing a port. Nevertheless, in the case of the port of Genoa this element may be considered important yet not have great influence in the decision process since it is similar to all companies.

A descriptive statistic approach shows that the average number of employees of the freight forwarders in the sample is 47,1 and the average annual sales was 23,6 million euro in 2007. Another indicator of the company dimension is related to the legal company form and in our sample 50% of the forwarders are Public Limited Company, 46% Limited Liability Company and just 4%, i.e., 1 company is a Commercial Partnership.

It was asked in the questionnaire who takes the decision of choosing a port: the forwarder, the sender or the consignor of the good. The results show that for 65% of the companies the forwarder is the operator who chooses the port, the 19% of the companies declared that the sender or consignor selected the port with the forwarder, 8% declared that the sender chooses the port and 2 companies did not answer to this question.

The data collected on the freight forwarders perspective of the relevance of the 31 variables listed, which represent the elements potentially affecting the choice of port, was analysed using the FA method. After performing the FA our results brought us to have 4 factors affecting the choice of selecting a port from a forwarders point of view. These factors are:

1. Connectivity of the port;
2. Cost and Port Productivity;
3. Electronic information;
4. Logistics of the container.

These 4 factors explain 61,45% of the total variance, while the first factor alone accounts for 34% of the total variance, as can be seen from table 2.

It can be observed that the first factor constitutes the most important criteria that the freight forwarders stated to consider when choosing a port. This result appears clear when looking at the scree plot, the first factor is considerably above an eigenvalue of one (Fig.2). There is clear distinction between Factor 1 and all the other components.

TABLE 1  
Rotated Component Matrix

Variables	Factors			
	F 1	F 2	F 3	F4
Customs procedures	,799	,118		,266
Elect Customs proc	,758	,321	,285	,194
Handling facilities	,716	,113	,400	
Customs efficiency	,714	,323	,335	
Customs hours	,682	,408	,292	,129
Rail connections	,645			
Rail cost	,603	,293		
Fill in/ clear out proc	,579	,113	,378	,548

Maritime agents	,538	-,361	-,161	
Freq maritime service	,518	,322		,138
Hinterland connection	,461	,433	,139	
Road connections	,436			,145
Road cost		,748	,102	-,151
Transit time		,734		
Port charges	,109	,693	,308	,259
Working port hours	,345	,665	,221	,253
Terminal competition	,262	,615		,471
Maritime companies competition	,324	,604	-,102	,553
Terminal productivity	,149	,591	,505	,417
Strikes	,135	,536	,352	,424
Added value services	,300	,517	,351	-,150
Warehousing	,311	,480		
Track/trace		,191	,801	-,138
Electronic information	,197	,219	,788	-,193
Physical condition container	-,112		,769	,280
Total time container in port	,200	,162	,689	,199
E-commerce	,341		,660	
Booking documentation reliability	,306		,567	,457
Availability empty container port	,115		,128	,888
Availability empty container inland port				,883
Location taking/delivering container	,107		-,158	,708

The first factor named “*Connectivity of the Port*”, comprises several variables related to customs procedures and characteristics, such as customs procedures (0,799), electronic customs procedures, (0,758) followed by customs efficiency, customs hours and fill in and clear out procedures. This element is particularly relevant for the freight forwarders since it is related to the legal procedures the goods have to follow for entering and exit the port. An other variable strictly related to the connections that the port has with the several stakeholders is handling facilities, also this variable score very high. (0,716).

The relevance that forwarders give to hinterland connections is represented by the variables related to the road/train connections and costs. The rail component, connections (0,645) and costs (0,603), score more than road connections (0,436); also the generic variable hinterland connections is present in factor 1. Road, rail and hinterland connections constitute the physical connections that the port requires. Other variables related to the connections of the ports are the presence of maritime agents and the frequency of the maritime service; both these two variables score lower in factor 1. It is relevant to focus the attention on the tree first variables of Factor 1, two of them are related to customs activities and the third is more related to the facilities of the terminal. These elements constitute, according to this study, the most important elements that are considered when choosing a port.

The second factor titled “*Cost and Port Productivity*” comprises 10 variables that are related to the port itself and the activities and services offered. The first variable, road costs together with port charges are the cost variables of the factor. They are in the first and third position of correlation with the Factor 2. (0,748 and 0, 693). The only other variable relate to the costs of the port is rail cost, that belong to Factor 1, it can be

notice, nevertheless that the variable rail cost score very high in correlation with Factor 2. All the others variable are strictly related to the activities and characteristics of the port, as transit time, that has a correlation of 0,734 with the factor 2, or the number of operational hours of the port, (0,665). The competition among terminal operators and maritime companies is also considered relevant when choosing a port, together with the terminals productivity. The last variables comprised in factor 2 are: strikes (0,536), added value services (0,517) and warehousing (0,480).

Factor 3 corresponds to “*Electronic information*” thus named since the vast majority of the variables included in this factor are related to information technologies and exchange of information. The variable that score the highest correlation with the factor is the possibility to track and trace the goods (0,801) followed by relevance of electronic information (0,788). The third variable in this factor is not really related to factor 3 since it refers to the physical conditions of the containers. A possible explanation of the presence of this variable in this factor could be that the container itself is not managed or controlled by the port but by the maritime company that own the container. In most cases the physical condition of the container does not change from port to port, thus it seems not to be a crucial criterion. It is important to remember that this is the result of a mathematical elaboration that does not take into consideration the sense of the variables, which sometimes could contrast with the statistical or mathematical approach. The other variables included in factor 3 are, in order of relevance, total time of the container in the port (directly related to the availability of electronic procedures that allow a faster operation), e-commerce and booking and documentation reliability.

The fourth factor is identified as “*Logistics of the container*” and the three variables correlated with this factor are availability of the container in the port (0,888), availability of the container in the inland port (0,883) and location for taking and delivery of the container (0,708).

Summarising, using the FA it was possible to identify 4 Factors that shed light in to which elements influence forwarders when choosing a port for their operations. These four factors, in order of importance, are:

1. Connectivity of the Port;
2. Cost and Port Productivity;
3. Electronic information;
4. Logistics of the container.

These 4 factors explain 61,45% of the total variance, while the first factor alone accounts for 34% of the total variance. It can be observed that the first two factors – connectivity of the port and cost and port productivity - explaining 44%, constitute the most important criteria that the freight forwarders stated to consider when choosing a port.

What has been concluded in this paper follows the finding of the previous literature dealing with this topic. As Lirn et al. (2004) remark the location of the port is crucial in choosing a port, as well as the administrative and management aspects; our results were also in line with Song and Yeo (2004) study, where they stress the importance of port location, service level and port expenses.

## 6. CONCLUSIONS

A review of the literature on port choice revealed that considerable research has been conducted on this topic. Several studies rely on surveys of port users to get information on factors influencing port choice. It is also common the use of Analytic Hierarchy Process (AHP) to prioritize survey responses in a determined way by giving weights to various factors. An alternative approach to research the factors influencing port choice is to base the analysis on the observed port decisions. A case study with 26 forwarders operating in the port of Genoa was performed. The results of the FA lead to the conclusion that the main factors affecting the forwarders port choice behavior are four: connectivity of the port, factor 1, cost and port productivity, factor 2, electronic information, factor 3 and logistics of the containers, factor 4.

The outcome of this statistical approach leads us to confirm what was already argued in the literature review and allow us to support mathematically what can be learned from the know how and common knowledge of the forwarders. The main problems of the port of Genoa are related to its location, port (in)efficiency and to the time spent in the operational procedures due to bureaucratic and administrative reasons. These elements seem to be, at the same time, the main criteria that the forwarders consider. Therefore, the growth and future development of the port of Genoa depends on proactively solving these issues.

It would be interesting to further research this topic analyzing more port users and also different types of ports.

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## DETERMINATION OF OPTIMUM FLEET SIZE AND COMPOSITION – A CASE STUDY OF RETAILER IN THAILAND

*Terdsak RONGVIRIYAPANICH<sup>1</sup> and Kawee SRIMUANG<sup>2</sup>*

**Abstract** — Management of freight transportation for retail business, which employs both owned fleet and hired vehicles, is a challenging task. Logistics manager has to make a decision on the optimum fleet size as well as a composition of owned fleet and hired trucks. The objective of this study is to determine the optimum fleet size and composition in order to minimize the transportation cost with consideration on desired level of service. The proposed fleet management was compared with the actual operation of a case study in 2007. The result showed that efficient route sequencing and fleet size optimization can reduce the transportation cost by 4.2 percent. Sensitivity analysis revealed that cost saving may need to be traded off for better on time performance.

**Keywords** — fleet size and composition, vehicle routing, on time performance

### BACKGROUND

Retailer has to deal with distribution of goods to its stores which may be geographically dispersed. The major factors affecting choice of transportation service provider are cost, reliability, flexibility and responsiveness [1]. Recently, some shippers have opted to outsource the distribution to third party logistics provider in order to save transportation cost. Nevertheless, some shippers still maintain owned fleet in order to ensure flexibility and responsiveness of the service. Due to variation of demand over the year, shippers face with difficulties in determining optimum fleet size and composition. The operating cost of owned fleet is lower than that of hired vehicles. However, fixed cost of owned vehicle is high, unless it is efficiently utilized. From this viewpoint, the goal would be to maximize owned fleet utilization and outsource excess load to third party logistics provider as proposed in [2].

TOPS supermarket, which is a leading retailer in Thailand, is chosen as a case study. Fleet management in TOPS is still relying on expert judgment with support of real time vehicle location data. Thus, saving algorithm [3] will be employed to ensure that vehicles are utilized in the most efficient manner. A distribution center is located in Bangkok Metropolitan Region, in which 75 percent of the stores are located. At present, TOPS is employing both owned fleet and hired vehicles to transport goods from the distribution center to its 96 stores nationwide. The study will examine the optimum fleet size and composition for the case study. Nevertheless, optimum fleet size in terms of cost may not yield a desirable level of service. Thus, sensitivity analysis of fleet size and on time performance will be performed.

### OBJECTIVES

The objectives of this study are as follows.

- To compare the efficiency of vehicle routing using saving algorithm with that of manual method.
- To determine optimum fleet composition and saving in transportation cost
- To examine effects of fleet size on the on time performance

### METHODOLOGY

Methodology employed in this study can be summarized in Figure 1. Firstly, we created a GIS map of distribution center (DC) and the stores using ArcGIS. It was then used to build distance matrix of the network. Distance between each origin and destination is determined by finding the shortest route on the road network in ArcGIS. Delivery time is assumed to comprise service and travel time. Service time, which is necessary for loading and unloading, is assumed to take a fixed value of 1.5 hour. Travel time is determined by assuming average speed of 56 km/hr in urban area and 75 km/hr on highway.

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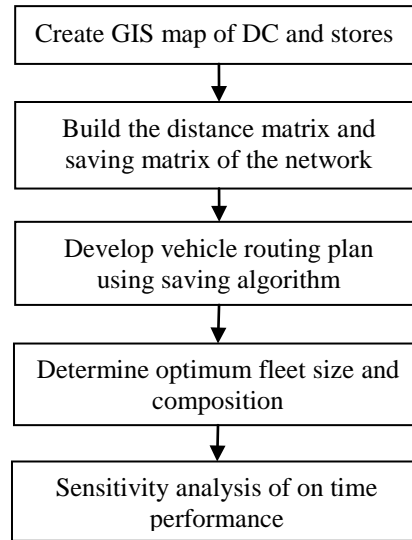


FIGURE 1  
Research Methodology

### Vehicle Routing

Actual shipment data in 2007 is used as input data for vehicle routing. Each shipment data consists of store name, ordered products, weight and time of delivery. Initially, each route is assigned to each store. Feasibility of combining store  $i$  and  $j$  into the same route is considered in terms of constraints on time windows and vehicle capacity [4]. This is to check whether

$$e_j \leq l_j \text{ and}$$

(1)

$$D_i + D_j \leq Q$$

(2)

where

$e_j$  = earliest time of delivery to store  $j$  ( $e_j = \max(e_j, e_i + T_{ij})$ )

$e_i$  = earliest time of delivery to store  $i$

$l_j$  = latest time of delivery to store  $j$

$T_{ij}$  = delivery time between store  $i$  and  $j$

$D_i, D_j$  = demand for store  $i$  and  $j$

$Q$  = vehicle capacity

If combining stores  $i$  and  $j$  into the same route is feasible, saving obtained from the combined route will be given as follows.

$$s_{i-j} = c_{DC-i} + c_{DC-j} - c_{ij}$$

(3)

where

$s_{i-j}$  = saving obtained from the combined route of store  $i$  and  $j$

$c_{DC-i}$  = distance between DC and store  $i$

$c_{DC-j}$  = distance between DC and store  $j$

$c_{i-j}$  = distance between store  $i$  and  $j$

A numerous studies on vehicle routing algorithms have been presented recently [5-7]. These studies proposed meta-heuristic algorithms, which proved to be more efficient than the original saving algorithm. Anyway, due to the limitation on number of stores which could be combined into a route, we opted to employ the original saving algorithm for the sake of computational simplicity. The algorithm for solving vehicle routing problem with time windows, developed in VBA for Microsoft Excel, is employed to the actual shipment data in 2007. The results are given in terms of the number of required vehicles for daily operation.

### Fleet Size and Composition

Due to variation of demand over the year, it is recommended that shippers cover base load by owned fleet and hiring vehicles to cover excess demand. Under the assumption of identical vehicles, Ghiani et al. (2004) proposed the least cost mix of owned and hired vehicles as follows.

$$C(v) = nc_F v + c_v \sum_{t=1}^n \min(v_t, v) + c_H \sum_{t: v_t > v} \min(v_t - v) \quad (4)$$

where  $C(v)$  = annual transportation cost  
 $c_F$  = fixed cost per time period of an owned vehicle  
 $c_v$  = variable cost per time period of an owned vehicle  
 $c_H$  = cost per time period of hiring a vehicle  
 $v$  = decision variable corresponding to the number of owned vehicles  
 $v_t$  = required number of vehicles for time period  $t$  ( $t=1,2,3,\dots,n$ )

Let  $m$  = the number of time periods per year in which  $v_t > v$ . The minimum annual transportation cost is achieved when the derivative of  $C(v)$  with respect to  $v$  is zero. Thus,  $C(v)$  is minimal when

$$nc_F + c_v m - c_H m = 0 \quad (5)$$

Hence, the optimal fleet composition can be determined by requiring that

$$m = n \frac{c_F}{c_H - c_v} \quad (6)$$

### Sensitivity Analysis

Optimum fleet size in terms of cost may not result in the desired service quality. Variation of demand over the year results in peak period, in which demand can not be served by the optimum fleet size. In such case, on time delivery can not be achieved. Thus, we will examine the effects of fleet size on the on time performance as measured by a percentage of time periods, in which demand can be served by available fleet.

## RESULTS

### Vehicle Routing

Figure 2 shows the number of required vehicles over the year 2007 as obtained from the actual operation and saving algorithm. Daily demand is variable, thus the number of required vehicles also varies over the year. Nevertheless, it is clear that efficient vehicle routing can reduce fleet size as shown by a decrease in the average number of required vehicles from 70.4 to 59.4 vehicles daily – a decrease of 15 percent. Figure 3 shows the effects of change in vehicle routing on fleet utilization. Owned fleet is utilized more efficiently as shown by an increase in the average running distance from 615 to 705 km per day. On the other hand, hired vehicles are utilized less as shown by a decrease in the average running distance from 316 to 265 km per day.

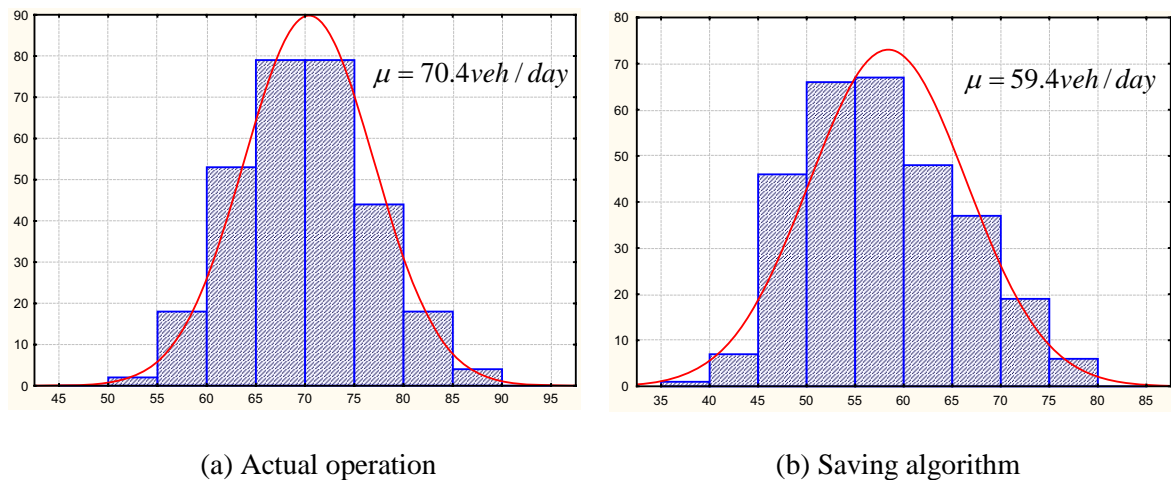


FIGURE 2  
The Number of Required Vehicles Daily in 2007

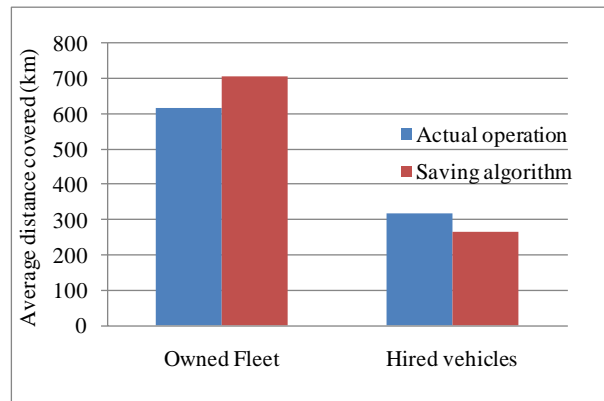


FIGURE 3  
Comparison of Vehicle Utilization

### Optimum Fleet Composition

Optimum fleet composition can be determined by using (6). Daily operation is considered as a time period, resulting in  $n = 365$ .  $c_F$ ,  $c_V$  and  $c_H$  are based on actual data of the case study with the values of 4.2, 7.84 and 15.99 baht/km respectively [8].

Optimum fleet composition for the case study is equivalent to 53 owned and 7 hired vehicles, compared to 49 owned and 22 hired vehicles employed in the actual operation. Due to lower cost of owned fleet ( $c_F + c_V < c_H$ ), the annual transportation cost can be saved by 4.2 percent or equivalent to 7.3 million baht yearly.

### Sensitivity analysis

Table 1 summarizes the on time performance with respect to the number of hired vehicles. It can be seen that the optimum fleet size produces 63 percent on time delivery. If 85 percent on time delivery is to be achieved, the number of hired vehicles must be increased to 14. Consequently, annual cost saving is reduced to just 2.8 percent. It is clear that on time performance is very sensitive to fleet size. Therefore, it must be incorporated into the decision on fleet size and composition.

TABLE 1  
On Time Performance under Different Fleet Size

Number of hired vehicles (Veh/day)	On time delivery (%)	Total truck (Veh/day)	Cost saving (%)
0	29.6	53	5.6
6	50.0	59	4.4
7*	63.0	60	4.2
14 (+1.70 $\sigma$ )	85.0	67	2.8
16 (+1.95 $\sigma$ )	90.0	69	2.5
19 (+2.31 $\sigma$ )	95.0	72	1.9

\*optimum number of hired vehicles

\*\* standard deviation of number of required vehicles ( $\sigma$ ) = 8.11 vehicles/day

### CONCLUSIONS

Management of freight transportation for retail business, which employs both owned fleet and hired vehicles, is a challenging task. The operating cost of owned fleet is lower than that of hired vehicles. However, fixed cost of owned vehicle is high, unless it is efficiently utilized. From this viewpoint, the goal would be to maximize owned fleet utilization and outsource excess load to third party logistics provider. TOPS supermarket, which is a leading retailer in Thailand, was chosen as a case study. Vehicle routing with time windows was employed to ensure that vehicles are utilized in the most efficient manner. It is proved that efficient vehicle routing can save the average number of required vehicles compared to the actual operation. The effects of change in vehicle routing on fleet utilization were also observed.



The study also examined the optimum fleet size and composition for the case study. The result shows that efficient route sequencing and fleet size optimization can reduce the annual transportation cost by 4.2 percent or equivalent to 7.3 million baht yearly. Sensitivity analysis indicated that logistics manager needs to trade of cost saving against desired service quality.

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## NEW CONTAINER PORT DEVELOPMENT: FORECASTING FUTURE CONTAINER THROUGHPUT

*Dimitrios TSAMBOULAS<sup>1</sup>, Panayota MORAITI<sup>2</sup>*

**Abstract** — Container ports constitute nowadays important nodal points in the entire global logistic chain of containerized freight. Forecasting the container throughput to a new port is a challenging task. This paper presents a simple methodology for carrying out an initial forecasting of future container traffic through a new port to be constructed, at the preliminary stage of planning. It is, therefore, aimed at providing a planning context for informed decision making by governments, shipping lines and port authorities, as well as potential investors and global port operators. The methodology has been applied for estimating demand for a proposed port development in Greece.

**Keywords** — container throughput, forecasting, logit model

### INTRODUCTION

The shipping and port industry must respond to a new reality. The ongoing globalization processes, the current transport needs related to consumer and production patterns and the recent economic and technological changes, have created a new environment, full of challenges for all interested parties. The continuing growth of world trade, particularly from emerging economies, such as China, has resulted in increased demand for transport services, whilst the advantages of seaborne transport in terms of economic efficiency, security and safety, as well as environmental protection have become obvious.

On the other hand, there is a strong emergence of global operators, as a result of policy measures that enhance competition, as ports tend to be divided into competing terminals and national monopolies are being decentralized, leading to new market opportunities for companies to operate further than the confines of their origin countries' borders. Therefore, container ports constitute at present important nodal points in the entire global logistic chain of containerized freight, and there is a continuously increasing demand for them and their related services, resulting in low-risk investments in this sector.

Short Sea Shipping, according to the European Commission, is the only transport mode able to keep up with the rapid economic growth of the EU, and is, therefore, regarded as the only freight mode that offers a realistic prospect for substantial modal shift from road in the future, as well as the one contributing to improving competitiveness, reducing environmental damage, and enhancing cohesion in an expanding EU [1].

More specifically, a similar initiative, the Motorways of the Sea, has as its main objective the improvement of the existing maritime links or the establishment of new, viable, regular and sufficiently frequent maritime links for the transport of goods, resulting in the concentration of transport flows on a selection of ports or port regions in a door-to-door logistics chain. The development of the ports and their hinterland connections not only contributes to the reduction of transport costs and the promotion of an environmentally friendly transport mode, but also meets the requirements of an intermodal transport system.

The forecasting of container throughput to a new port is a challenging task. By providing cargo throughput forecasting and thus future shipping network requirements, port authorities or governments can set up master plans for port development, whilst shipping lines can improve their investment plans.

This paper presents a methodology for carrying out an initial forecasting of future container traffic through a new port to be constructed. This is aimed at providing a planning context for informed decision making by governments, shipping lines and port authorities in the region in hand, as well as potential investors and global port operators. The proposed methodology consists of two different forecasting methods, the first based on the attraction of existing flows, with a scope to obtain an upper limit on the value of the future container throughput and to provide input to the second one, a probabilistic approach, based on the application

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of a Logit Model. The forecasting methodology has been applied for the specification of the demand for the proposed development of a new port in the south of Greece.

## BACKGROUND

Various port authorities use different methods to forecast traffic of general cargo. A number of them rely on externally produced international trade forecasts and use shift and share methods by broad commodity groups, to estimate what part of the trade of the country will go through each port. Others use trend extrapolations or a mixture of trend analysis and shift and share [2].

In general, port cargo volume is directly related to the level of external trade and the macroeconomic conditions. Thus, regression analysis is often carried out, to relate variations in cargo throughput to variation of economic indicators [3]. In addition, Hong Kong, the busiest container port in the world, has been using a regression analysis approach to forecast port cargo throughput for its port planning and development over the decades [4]. Moon [5] has examined the validity of the port input-output model (PIM) as predictive tool to future planning for identifying the impact of the port industry and calculating the spreading effects of the port industry on the nation's economy.

In another approach, aimed at developing an integrated model for forecasting both the number of ship visits and their characteristics, knowledge of future shipping trends for any port was considered, as the future number of ship visits and their characteristics may have implications for the physical facilities of a port. The proposed model identified the major economic determinants as the expected trade throughput, world shipping trends, standards of facilities and future plans of shipping companies/agents [6].

Finally, Zohil and Prijon, [7] in their forecasting of transshipment volumes in the Mediterranean ports, concluded that transshipment volumes depend on the diversion distance and the total traffic throughput. In more detail, the volume of cargo transhipped in a single port is an inverse linear function of the distance of the port from the main-line vessels' route transiting the Mediterranean, and a linear function of the port container traffic volumes.

## METHODOLOGY

The methodology proposed in this paper is applied on the proposed development of an international container port in the south of Greece, with a view to provide connection to other big ports in the Mediterranean, as well as the Far East (Singapore, China, Korea, Japan and Taiwan) and India. At this preliminary stage, a detailed development and operational plan is not necessary. Any feasibility study, however, would have to include a forecasting methodology. As described in the previous section, there are several ways to estimate the attracted traffic to the new container port. Consequently, in order to explore all possibilities, and take into consideration the fact that the port is not yet in operation, so that actual values could be obtained, it is proposed to employ two distinctive forecasting methods with a scope to derive a more realistic estimate, based on the outputs of each of these methods.

### Attraction from Existing Routes

The first approach entails a simple record of existing flows and a crude assumption of how traffic will be attracted to the proposed port. This assumption is based on the "potential" traffic that can be diverted to the port from existing routes. Thus, this method presents the maximum traffic (upper limit) and can be used as a benchmarking value to provide input to the other methods. It assumes a common rate for transshipment costs, regardless of the port.

Direct calling is more profitable than transshipment according to shipping costs, mainly by virtue of the extra feeder costs and container lift charges involved [8]. In other words, in case of intra Mediterranean or Mediterranean-Europe trade routes, wherever transshipment occurs at any ports, the associated costs are more than direct calling. Therefore, container cargo derived from the economic area around the south of Greece will not be transhipped at the New Container Port in order to be shipped to other European and Mediterranean ports. Possible container throughputs will be from ships calling at Gioia Tauro, Taranto, Port Said, Malta, and Piraeus for the trade routes between the western Mediterranean & Black Sea countries (such as Greece, Romania, Bulgaria, Ukraine, Russia, Turkey) and North American & Asian countries, Australia and South Africa. Based on the above assumptions, Table 1 presents the methodology for forecasting the future container throughputs of the New Container Port.

Based on the actual traffic data for the base year 2005 [9]-[10], the estimated traffic that could be attracted by the New Container Port is presented in Table 2.

TABLE 1  
Forecasting Methodology 1

<i>Countries</i>	<i>Possible Trade Routes &amp; Container Throughputs</i>
Greece(GR)	Total Container Throughputs of Greece - {(Trade Volume btw GR & EU) + (Trade Volume btw GR & Med.) + (Trade Volume btw GR & Asia & N. Am. using Ocean Going Direct Calling Trade Route-OGDCTR)}
Romania(RO)	Total Container Throughputs of Romania - {(Trade Volume btw RO & EU) + (Trade Volume btw RO & Med.) + (Trade Volume btw RO & Asia & N. Am. using OGDCTR)}
Bulgaria(BG)	Total Container Throughputs of Bulgaria - {(Trade Volume btw Bu & EU) + (Trade Volume btw Bu & Med.) + (Trade Volume btw Gr & Asia & N. Am. using OGDCTR)}
Ukraine(UR)	Total Container Throughputs of Ukraine - {(Trade Volume btw UR & EU) + (Trade Volume btw UR & Med.) + (Trade Volume btw UR & Asia & N. Am. using OGDCTR)}
Black Sea Area, Russia(BSR)	Total Container Throughputs of Russia - {(Trade Volume btw BSR & EU) + (Trade Volume btw BSR & Med.) + (Trade Volume btw BSR & Asia & N. Am. using OGDCTR)}
Turkey(TK)	Total Container Throughputs of Turkey - {(Trade Volume btw TK & EU) + (Trade Volume btw TK & Med.) + (Trade Volume btw TK & Asia & N. Am. using OGDCTR)}
Cyprus(CY)	Total Container Throughputs of Cyprus - {(Trade Volume btw CY & EU) + (Trade Volume btw CY & Med.) + (Trade Volume btw CY & Asia & N. Am.(incl. W. Africa) using OGDCTR)}

TABLE 2  
Estimated Container Throughputs of the New Container Port (TEUs)

<b>Countries</b>	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>A-B-C-D</b>
<b>Greece</b>	1,779,030	726,631	386,018	396,128	349,436
<b>Bulgaria</b>	110,085	46,502	48,726	NA	67,939
<b>Romania</b>	771,126	117,891	160,299	172,266	355,123
<b>Ukraine</b>	458,258	177,649	NA	35,577	252,174
<b>Black Sea Area in Russia</b>	161,756	39,878	NA	NA	121,878
<b>Turkey</b>	3,170,357	1,800,791	NA	856,307	792,520
<b>Total</b>	6,450,612	2,909,342	595,043	1,460,278	1,939,070

Where: A (Total Container Throughputs), B (Total Volume with Europe), C (Trade Volume with North Africa (including Mediterranean)), D(Trade Volume with Asia & North America using OGDCTR), and E(Trade Volume with Asia & North America using OGDCTR)

### Application of the Logit Model

The second method involves the application of the Logit Model [11], which has been by far the most widely used in the field of transport mode and route choice studies. The formulation is developed in a utility context of a binary choice situation, in the form of (1):

$$P(i) = \exp V_i / (\sum [\exp V_i + \exp V_j]) \quad (1)$$

where,

$V'$  = the vector of unknown parameters  $X$ , with coefficients  $\beta$

$x$  = a vector of attributes.

$$V = c + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_n X_n$$

With regards to the variables to be included in the model, Mangan [12] identified the following hierarchy of the key variables affecting the choice of mode/route:

- Cost/price/rate
- Speed
- Transit time reliability
- Characteristics of the goods
- Service

Other key variables also assessed by Witlox [13] were reliability, flexibility and damage and loss.

In transshipment, cargo moves through intermediate ports in its journey from origin to destination. These journeys are increasingly managed and designed to achieve the minimum point-to-point generalized transport cost, and not merely the minimum distance transport cost as before [14]. Hence, for the purpose of this study, it is assumed that the travel time and frequency of service, as well as reliability and quality of service will not differ significantly amongst the routes, and hence the decisive variable will be the travel cost. Also, since there is no possibility of introducing disaggregate data, the values for the variables introduced to the models are related to average values, derived from aggregate data

Hence, (1) is employed to express the “probability of choosing the New Container Port”, as follows:

$$P(\text{New Container Port}) = 1 / (1 + e^{UI}) \quad (2)$$

where,

$$UI = 1,73 - 0,018 C \quad (3)$$

The value of 1,73 represents the constant that reflects the relative attractiveness of the New Container Port. The value of 0.018 is a coefficient based on other similar studies [15].

Based on the above, travel costs are calculated for the routes and ports assumed in the first forecasting methodology. Since in this case, the critical value is the transshipment cost, an average value for the New Port is proposed, set at 84 US dollars per TEU [16]. Since the exact value is not known in advance, the forecasting methodology will be carried out for three distinct scenarios with respect to the transshipment cost of the proposed port, based on the transshipment values of 67\$ (low), 84\$ (medium) and 99\$ (high).

Based on the results of Table 2 in the previous section, and on the methodology described, Table 3 presents the predicted container throughput for the base year 2005, for the three scenarios of transshipment cost considered.

TABLE 3  
Predicted Container Throughput to New Container Port 2005 (TEU)

Countries	Estimated container throughput to New Port (max. Values)	Probability of choosing New Port			Possible container throughput to New Port for year 2005		
Transshipment cost at the New Port		\$99	\$84	\$67	\$99	\$84	\$67
Greece	349436	0,2760	0,3328	0,4036	96441	116308	141034
Bulgaria	67939	0,2760	0,3328	0,4036	18750	22613	27420
Romania	355123	0,2760	0,3328	0,4036	98010	118201	143329
Ukraine	252174	0,2872	0,3454	0,4172	72430	87092	105213
Black Sea Area,Russia	121878	0,2872	0,3454	0,4172	35006	42092	50850
Turkey	792520	0,2872	0,3454	0,41722	227629	273707	330657
	<b>1939070</b>				<b>548267</b>	<b>660014</b>	<b>798503</b>
<b>Total</b>							

In the case of the base year 2005, the predicted container throughput for the average transshipment cost of \$84, is estimated at 660 014 TEU. It should be noted that this value is well below the upper limit that has been estimated and presented in the first column (1 939 070 TEU). Finally, in order to obtain values for any target year that the New Port would be operational, using linear extrapolation, an average growth factor could be applied to the predicted demand for 2005.

In the absence of sufficient data, the model was neither calibrated nor verified. Nevertheless, Giannopoulos [17] used a similar, albeit more complex, Logit model in order to model the transshipment port choice situation in the same region, with the relative utility function defined as a composite measure of two utilities: one that relates to the distance between the origin and the destination port, and one that relates to the “level of service” (likely) to be offered by the destination port. The results indicated a future attraction of 650 000 containers for the same year, which is directly comparable to the container throughput predicted by the methodology proposed in this paper.

## CONCLUSIONS

New trends in the economy, policy, and technological frameworks in the Mediterranean have lead to the development of new container shipping activities operating in the region, together with the evolution and growth of transshipment ports. In this context, this paper presented a simplified, novel and less data intensive methodology for forecasting future container traffic applied to a proposed New Container Port in the southern part of Greece.

The methodology consisted of two approaches, the first being more general in nature, with the scope to obtain an upper limit on the future container throughput and to provide input for the second approach. In the latter, a port choice model was set up, based on the assumption that travel cost is the determining variable. Given its nature, the proposed methodology could be employed at the preliminary stage of planning for cases where the port in hand is not yet in operation, providing thus, a planning context for feasibility studies, and provide indicative information for stakeholders such as governments, shipping lines, port authorities, potential investors and global port operators.

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## SEA PORT HINTERLAND FLOWS AND OPENING HOURS: THE WAY FORWARD TO MAKE THEM MATCH BETTER

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**Abstract** — Congestion at and around seaports has gained increasing media attention in the last years. This paper deals with the results of a research project on how to alleviate such congestion, and starts from the observation that the concentration of traffic is to a large extent due to the mismatch in opening hours at seaports and in the hinterland. The main research hypothesis states that a shift from peak hours to other moments during the hinterland working day, is the most viable option for shifting away traffic. Representative hinterland transport flows are selected upon statistical importance of flows and the type of goods. Three scenarios are considered: shifting to the late morning, the very early morning and the late working day. A shift to a moment within shipper opening hours is always the most feasible one. The largest benefit in all cases goes to the hinterland transport company. The largest cost usually goes to hinterland shippers.

**Keywords** — congestion, hinterland transport, opening hours, seaport, shift in time of day

### INTRODUCTION

It is often said that seaports are the engine behind economic growth. Of all factors that determine the logistics position of a country or region, the capacity and efficiency of gateways, like seaports and airports, is probably the most important one. With increasing international trade, this statement is probably more true than ever before. All links and nodes within a chain should match as well as possible. Each bottleneck is a potential destructor, no matter how well the rest of the chain functions, especially to the extent that the bottleneck is located in a crucial node or link. Seaports are in the latter situation. To some part of the hinterland, they might be the only gateway. In that case, hinterland accessibility is at stake. In other cases, several seaports might serve a hinterland. In such situation, competition between seaports will come into play.

Therefore, it is important to gain insight into the factors that impact on port efficiency and competitiveness. Past research, among others by [3] - [5], shows that a crucial competitive variable is potential time loss for ships, which can be incurred during the port entry or exit, or at berth. The latter may be caused by bad capacity management, lack of terminal capacity or congested hinterland connections.

Most seaports worldwide have registered large growth figures, especially those that are active in the container business. Growth has occurred in tonnage as well as employment and value added. This growth was often referred to as evident, referring to the naturally advantageous location of the seaport and the available knowledge and training, which translate into high throughput respectively productivity.

In the most recent years however, this evidence has disappeared. As far as containers are concerned for instance, the strongest threat is often no longer coming from neighboring seaports, but from ports in other port ranges, who have accumulated overcapacity. The competitive environment of seaports however has changed drastically over the last years, with competition getting fiercer among existing competitors, new competitors entering the market, and changing power of seaports at all in logistics chains.

Ports have a hard time in keeping up with capacity expansion. Space needs to be found, and funds are needed for investing. But even when port space and funds are available, there is yet another problem. Other links in the chain need to be able to follow. Recent research by [6] – [7] indicates that especially the latter is an issue at many seaports, in Flanders like in a number of other European seaports. The ongoing and planned

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expansion of maritime access and terminal capacity at many seaports will only worsen the hinterland situation, if no adequate measures are taken. This may imply that the new flows cannot be accommodated properly, but also that existing chains will experience worse service than before, impacting heavily on accessibility and competitiveness.

Shipping lines will not undergo such deterioration of service, but will react by repositioning maritime loops, changing ports of call or call frequency. A core rule is that economies that materialize through scale increase and cost reduction on the maritime side, should not be nullified by time losses and cost increases on the hinterland side. Such shift will in turn make the port less attractive for shipping commodities, and will lead to a reduction of employment and value added generated at the port. Furthermore, also production and service companies in the port's hinterland may relocate, again decreasing the level of employment and value added.

A first way in which governments have reacted, is by trying to shift part of the traffic away from the road to other hinterland modes, if available at all. However, in most cases, those modes can only accommodate a small share of the traffic. A second answer was completing the hinterland network with a number of missing links. Congestion however is in most cases a peak hour phenomenon, putting high pressure on transport infrastructure and logistics systems at well-determined moments of the day, while leaving the infrastructure inefficiently used at other moments of the day. Moreover, adding new roads and/or missing links is expensive and will most likely not be a structural solution, as new traffic will be attracted that will fill up the extra capacity, in most cases even not only port-related. In that case, a third solution may be sought for, namely trying to make better overall use of infrastructure by shifting certain operations in time, to moments where overall traffic levels are lower.

Shifting operations in time can be done in two ways: by extending opening hours at seaport terminals or in the hinterland, or by shifting the traffic to less congested moments during existing opening hours. Such shift can be enforced either by governments, like in Los Angeles [2], or by terminal operators, like in Felixstowe and Southampton [8]. In order to select the best measure or optimal combination of measures, it is necessary to have insight in the exact identification and location of bottlenecks, and in the level of supplementary benefits and costs which either of the two options involves. This paper deals with the two issues for a selected set of cases in Flanders, in an attempt to find an answer to the main research question: whichever of the two is better, shifting within existing terminal opening hours, or shifting towards extended opening hours.

The next section states the research hypothesis and the methodology used to test it. Section three deals with the context of hinterland flows and chain opening hours in Flanders. Section four elaborates on the flows that are selected for measurement and calculation, and the scenarios that are applied. Section five gives the quantified results of the calculations for the various cases and scenarios considered. The final section summarizes the main conclusions and provides a number of policy recommendations.

## **RESEARCH HYPOTHESES AND METHODOLOGY**

As the paper revolves around one major research question, the main hypothesis is this one: shifting within existing terminal opening hours is more efficient than extending terminal opening hours.

In order to test the hypothesis, first, a typology was made for classifying the different port-related hinterland flows. Second, statistical data were collected with respect to the importance of the various commodity groups and mode split of the Flemish ports, the geographical spread of port-related commodity flows around Antwerp, and a similar analysis based on the differentiation in time. Additionally, terminal-level truck calls were analyzed. The main input was a literature and data review on documents from the Flemish Community, the Flemish seaports, and terminal operators. Third, opening hours of the various actors involved in the landside of the logistics chains were assessed. Telephone and personal interviews were the main source of input. Fourth, based on the results from the previous steps, a selection of hinterland flows and shifting scenarios was made. Fifth, a model was developed, taking into account the results of previous measurement and calculation research. This model was used for calculating the supplementary costs incurred by all relevant actors in shifting traffic in time or in extending terminal opening hours, as well as the benefits that accrue from taking these measures.

### **PORT HINTERLAND FLOWS AND CHAIN OPENING HOURS: A TYPOLOGY**

Traffic flows between the seaport and the hinterland can be summarized into the typology of figure 1, according to their type of origin, destination and transport mode. The typology applies to Flanders, but is representative for most countries.

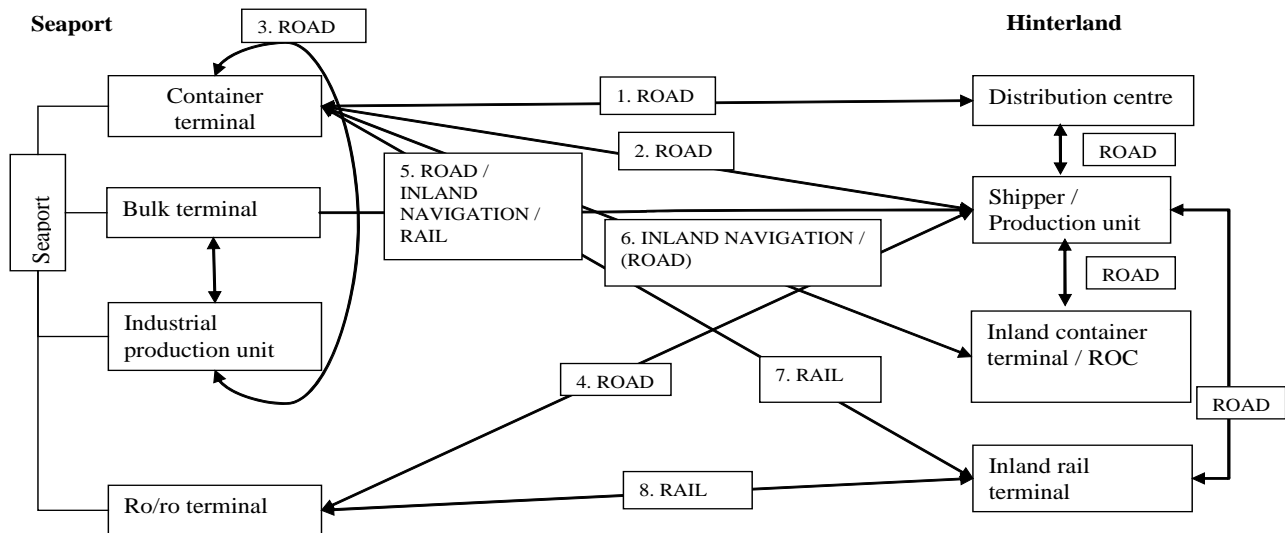


FIGURE. 1  
Port Hinterland flow Typology.

Following types of flows can be distinguished. Figures between brackets refer to the corresponding flows in figure 1. This typology is used as a structuring basis for the further research in this paper.

- From seaport container terminals to shipper or logistics service provider distribution centres in the hinterland and vice versa. An example of this kind of chain is the import of non-European products like computers, DVD players, etc. for large supermarket chains. (1)
- From seaport container terminals directly to hinterland shippers/production units and vice versa. An example is car components transported from seaports to car manufacturers outside the port. (2)
- From container terminals in seaports to industrial companies in the same seaport. An example is car components transported from terminals to car manufacturers in the same port. (3)
- From seaport ro/ro terminals directly to hinterland shippers/production units and vice versa. An example is paper pulp transported from a processing unit to foreign customers. (4)
- From seaport bulk terminals to hinterland shippers/production units and vice versa. An example is iron ore transported from a bulk terminal to a steel production plant. (5)
- From seaport container terminals to inland container terminals and vice versa. The bulk of these flows are handled by inland navigation. Only for urgent transport, road is used. Pre- and post-haulage between inland terminal and hinterland customers/shippers are done through road. An example is food shipped by using one of the inland terminals. (6)
- From seaport container terminals via rail to inland rail terminals and vice versa. An example is electronic components shipped through one of the rail terminals. Pre- and post-haulage between inland terminal and hinterland customers/shippers are done through road. (7)
- From seaport ro/ro terminals via rail to inland rail terminals and vice versa. An example is car traffic entering the country and using an inland rail terminal. (8)

With respect to chain opening hours, the disequilibrium between opening hours on the port side and the hinterland side is apparent from table 1. In all Flemish ports, it appears that the maritime side is open 24/24 and 7/7. The port landside in most cases shuts down at night, but the opening hours are still relatively long, especially in comparison to the hours that prevail in the hinterland. There, a distinction is to be made between small, medium-size and large shippers. Larger shippers are often open 24/24 as well. Medium-size shippers usually have opening hours that correspond to those at the port landside. Small shippers usually apply the regular office hours, and therefore are most limited.

TABLE 1  
Comparison of opening hours in the chain (2007)

	Maritime	Customs / Phyto-sanitary	Land		
			Truck	Rail	Barge
Antwerp					
Containers	7/7, 24/24	8h – 12h/12.30h + 12.30h/13h – 16.30h	6h – 21.30h	6h – 22h	6h – 21.30h
Bulk	7/7, 24/24	8h – 12h/12.30h + 12.30h/13h – 16.30h	8h – 15.30h	-	7/7, 24/24
Break bulk	7/7, 24/24	8h – 12h/12.30h + 12.30h/13h – 16.30h	8h – 15h	8h – 15h	8h – 15h
Zeebruges					
Containers	7/7, 24/24	6h – 22h / 8h – 12.30h + 13h – 16.30h	6h – 21.30h	-	-
Ro/ro	7/7, 24/24	6h – 22h / 8h – 12.30h + 13h – 16.30h	6h – 22h	-	-
Inland terminal			6h/8h – 18h/22h	6h/8h – 18h/22h	6h/8h – 18h/22h
Shipper			24/24, 8h – 17h	24/24, 8h – 17h	24/24, 8h – 17h

## CASES SELECTED FOR MEASUREMENT AND CALCULATION

Based on the importance of the commodity categories, the size of the freight flows and the mode split, this paper focuses on container terminals in the Port of Antwerp and on ro/ro and container terminals in the Port of Zeebruges. Of all modes, only pure road sections or combinations involving road among others are considered.

Five specific cases are selected, involving actual flows by road between various types of companies and various terminals, and considering the eventual involvement of actors like shipping companies, customs, agents, phyto-sanitary services, storage companies and forwarders.

A first case study concerns the export of containers by a medium-size shipper via the Port of Antwerp, as shown in figure 2. Red boxes indicate activities controlled by the shipping companies, green ones activities under the shipper's control, and black boxes show activities controlled by the forwarder. On average 25 containers take this route. The shipping company is also in charge of road transport (carrier haulage), and outsources that to a road transport company. Containers on chassis can be picked on and off at the shipper's premises 24/24 (from Monday 6am till Saturday 5pm). The shipper has a proper container lift to pick on and off containers. It is manned from 5am till 7pm. Alternatively, the chassis can also be left and changed for a different one.

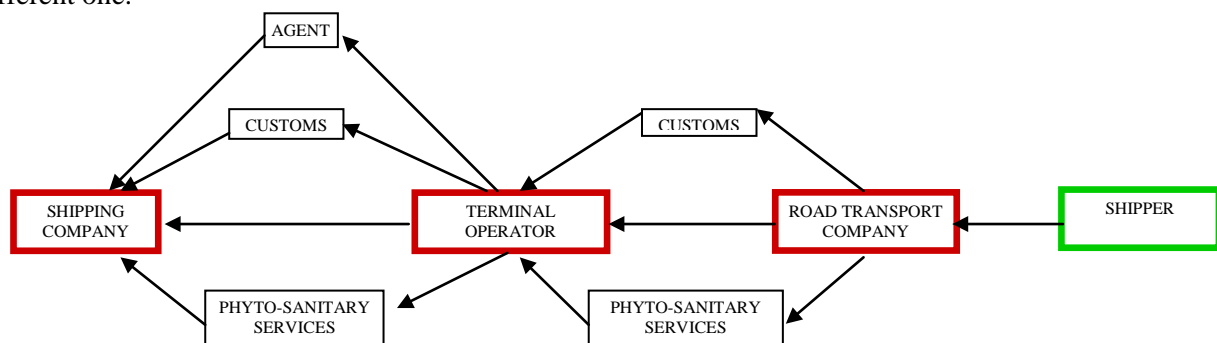


FIGURE. 2

Case 1: Container export through the Port of Antwerp.

A second case study, shown in figure 3, deals with export of containers by a small shipper via Antwerp, with intermediation by a forwarder. One container per week is transported this way. Containers can be picked up each working day from 7am till 4pm, but a clear peak is noticeable between 7am and 8am.

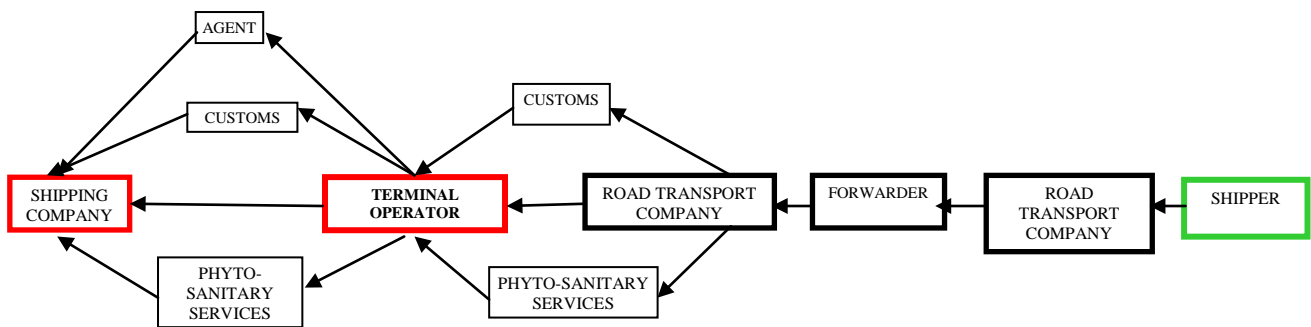


FIGURE. 3

Case 2: Container export through the Port of Antwerp via forwarder.

A third case study treats an importer using the Port of Zeebruges, shown in figure 4. Upon arrival in Zeebruges, containers are railed to the Port of Antwerp. From Antwerp, the containers are shipped to the shipper's warehouses by a fixed road transport operator. On a weekly basis, 115 containers are involved. From the distribution centres, the further dispatching to outlet stores is done by road transport again. The distribution centres operate in two shifts and are open from 6am till 10pm, and on Fridays till 8pm.

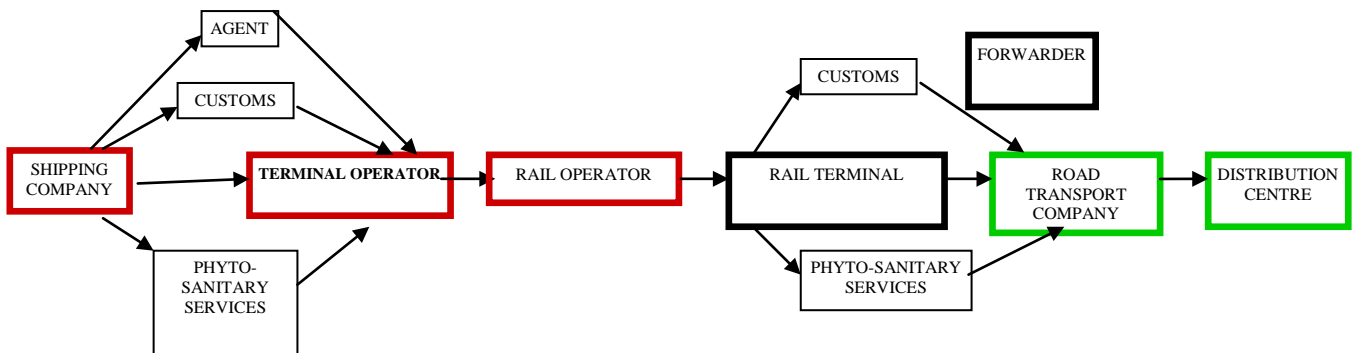


FIGURE. 4

Case 3: Container import through the Port of Zeebruges and via rail through the Port of Antwerp.

Fourth, import containers via Zeebruges are modeled, as in figure 5. 25 containers a week are involved. Containers can be delivered at the shipper's premises in two ways: by leaving the chassis, or by picking off. The latter is only possible between 5am and 9pm.

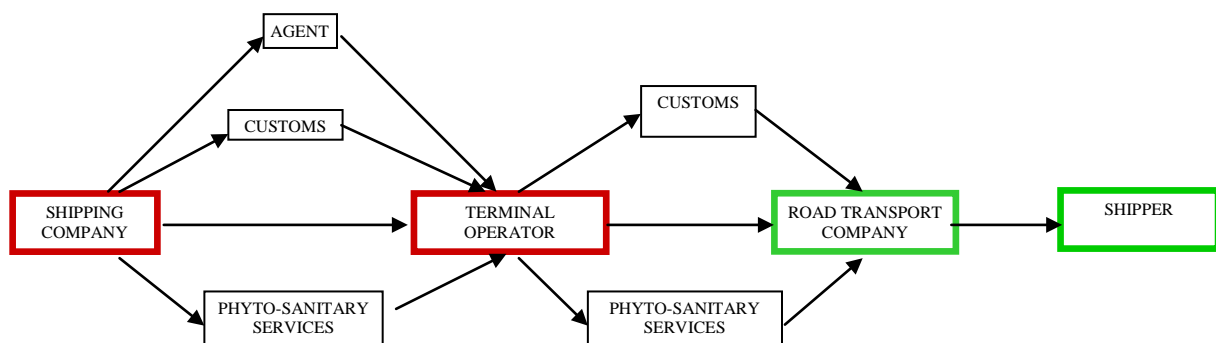


FIGURE. 5

Case 4: Container import through the Port of Zeebruges.

The fifth and final case concerns import of ro/ro through the Port of Zeebruges, represented in figure 6. Loading and unloading on the terminal are possible 24/24. Delivery at the shipper is theoretically possible between 8am and 6pm, but in practice there are limitations.

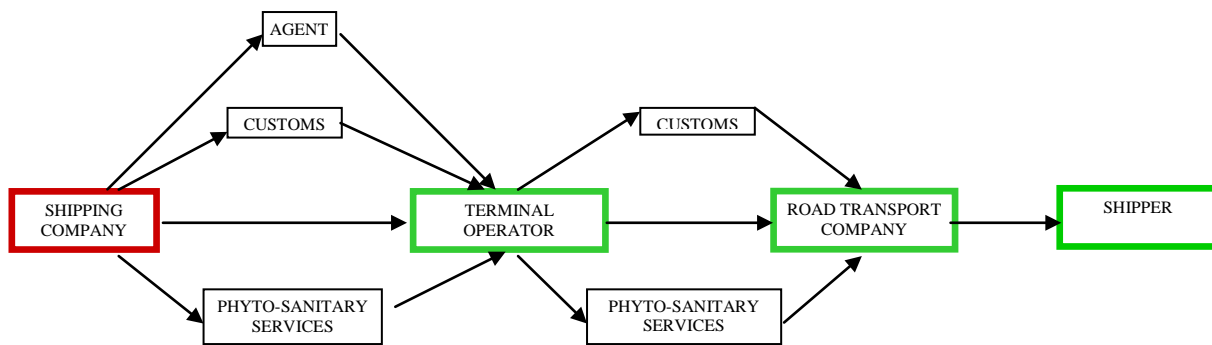


FIGURE. 6

Case 5: Ro/ro import through the Port of Zeebrughe.

Per case, different scenarios are developed and prepared for measurement in the next section. The scenarios depend on the moment to which the shift is made. A crucial variable is shipper size: for large shippers, there is no difference between night and day deliveries, as their services are open anyway. Small shippers on the contrary have strongly limited opening hours. The timing of the shift also impacts on the maritime side of port terminals: due to limitations in opening hours, supplementary costs need to be made for night deliveries.

### DIRECT COSTS AND BENEFITS OF SHIFTS IN TIME

For calculating costs and benefits for the various cases and scenarios described higher, following assumptions are made.

- The standard split-up of transport costs between time and kilometre costs, as described by [1] is used.
- External effects are not taken into account.
- The benefits of gaining time in transport equal the costs that are avoided. Not taken into account are the extra trips that can be made.
- Working hours are considered as night labour by applying the Belgian law: if for five consecutive nights, more than five hours are worked 8pm and 6am. If these conditions are fulfilled, a surplus wage applies.
- The period between 7am and 9am is considered the morning traffic peak, whereas the period between 4pm and 7pm is considered the evening peak.
- Terminal dwell times, waiting times at the gates and travel times are average values, not taking into account exceptional events.
- For night operations, an extra full shift is assumed.
- Due to the special regulation for customs night tariffs, no surplus value is assumed.

For case one, the starting situation is shown in table 2.

TABLE 2  
Case one starting situation.

Action	Duration	Tijdstip
Transport company arrives at shipper and puts off container		7.00am
Full containers is picked up	30min	7.30am
Transport company drives from shipper to container terminal in Antwerp, during morning peak	50min	8.20am
Processing of the container at the terminal (including gate waiting times)	90min	9.50am

Three alternative scenarios are considered, with two options each time: using a container elevator, or picking up and off entire chassis.

- An early morning (3am) start
- A late morning (10am) start

- A evening (7pm) start

In the first alternative, as compared to the starting situation, all actors incur supplementary costs, whereas only the transport company incurs a relatively small benefit. In the second alternative scenario, no extra costs are to be made, but the transport company incurs a small disbenefit due to longer gate waiting times. In alternative scenario three, the shipper incurs a surplus cost, whereas the transport company benefits from a small time gain. Therefore, in case 1, none of the alternatives means a real improvement to the current situation.

The general results for any possible alternative are summarized in table 3, per time block. Green boxes refer to no surplus cost, red ones to a relatively high surplus cost, and brown ones to a very high surplus cost. It turns out that especially the nights present prohibitive surplus costs to most actors.

TABLE 3  
Case one surplus costs compared to starting situation.

scenario with container elevator																								
	00:00	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
shipper	red	red	red	red	red	green	green	green	green	green	green	green	green	green	green	green	green	green	green	red	red	red	red	red
road transport operator	red	red	red	red	red	green	green	green	green	green	green	green	green	green	green	green	green	green	green	green	green	green	green	green
terminal	red	red	red	red	red	green	green	green	green	green	green	green	green	green	green	green	green	green	green	green	green	green	green	green
customs	red	red	red	red	red	red	red	red	green	green	green	green	red	green	green	green	red	red	red	red	red	red	red	red

scenario picking up and off entire chassis																								
	00:00	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
shipper	green	green	green	green	green	green	green	green	green	green	green	green	green	green	green	green	green	green	green	green	green	green	green	green
road transport operator	red	red	red	red	red	red	green	green	green	green	green	green	green	green	green	green	green	green	green	green	green	green	red	red
terminal	red	red	red	red	red	red	green	green	green	green	green	green	green	green	green	green	green	green	green	green	green	green	green	green
customs	red	red	red	red	red	red	red	red	green	green	green	green	red	green	green	green	red	red	red	red	red	red	red	red

For case two, the starting situation is the same, with that difference that travel times towards the port may be different because of a different starting location and distance towards the port. Only the early morning and late morning scenarios are now considered as alternatives. The evening scenario would be comparable to the late morning scenario, because the shipper is a big company, with extended opening hours. In the late morning scenario, the transport company earns a lower benefit than in the early morning scenario, but, at the same time, the surplus costs to all actors together are lower. Therefore, alternative two would be preferable in this case.

In case three, like in case two, only two alternative scenarios are considered, for the same reason. For these two alternatives, the benefit is equal and accrues entirely to the transport company. The surplus cost however is a lot higher under scenario one, and affects all actors. Therefore, just like in case two, scenario two is the better one.

Exactly the same conclusion as in case three applies to cases four and five, although the benefit is higher in case four, due to the time gain obtained at the terminal.

The overall results in terms of surplus costs for the different cases are summarized in table 4. Minor differences are observed between the cases, so that the overall lesson is that the heaviest surplus cost, to all parties concerned, is found for trips between 10pm and 6am, with some deviations according to the specific case considered.

## CONCLUSIONS AND POLICY RECOMMENDATIONS

The analysis in this paper allows narrowing down congestion problems in port-bound hinterland traffic to a limited time, geography and commodity type scope, and allows drawing a number of conclusions on the causes of the problem and the obstacles that prevent solutions from materializing. The time scope is clear: problems are strongest during morning and evening peak, and the calculations indicate that of the tested scenarios, shifting to other moments in the day overall gives the best result. Geography is important however, as the calculations show that not every trip origin results in the same benefits and surplus costs. Only containers were considered. It is probable that other commodity types might benefit from similar initiatives, although there again, benefits and surplus costs may be different.

Although the analysis focuses on Flanders, the conclusions are generalizable to a large extent to other countries with seaports, most of which experience similar problems. This type of initiative therefore certainly opens opportunities, and could be considered by any government of countries where similar inefficiencies occur.

More in-depth research is however needed, into the best alternative trip moment that could be suggested. Subsequently, a way of convincing actors of the benefits they obtain has to be found. A calculation tool like the one developed here could be helpful.

TABLE 4  
Case two-five surplus costs compared to starting situation.

case two

	00:00	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
verlader																								
hinterlandvervoerder																								
terminal																								
douane																								

case three

	00:00	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
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	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
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# INTERNATIONAL ROAD FREIGHT TRANSPORT IN GERMANY AND THE NETHERLANDS DRIVER COSTS ANALYSIS AND FRENCH PERSPECTIVES

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**Abstract** -: These last few years French international road freight transport has been undergoing a loss of influence within Europe while traffic has increased and great manoeuvres are taking place since the opening of the European Union towards East. Some of the French transporters are then focusing back on the French market showing a worrying loss in competitiveness. On the contrary, German and Dutch companies are increasing their shares in the French market and have reorganized themselves within Europe to face eastern Europe competition: follow-up on customers delocalizing in the East, networking, hyperproductivity, markets segmentation between high quality transport in the West, specific markets and low cost segment in eastern Germany or/and Poland, intensive geographical closeness to a great harbour (Rotterdam)... What should we learn from German and Dutch experiences to be used towards a renewal of French road transportation in the international field? On the basis of a comparison of our neighbours' driving costs and road freight transport structure, our contribution - a synthesis of two recent studies ordered by the Comité National Routier (CNR, studies free to be downloaded by [www.cnr.fr](http://www.cnr.fr)) - will first propose a cooperation with German or Dutch companies in order to propose a winner-winner model based on exchange of competencies : North Africa (Morocco for instance) and Southern Europe for French partners (specialization Storage - Logistics) and transport business model and opening towards the East for the German and Dutch partners. An interesting proposition would be to get close to Moroccan operators in order to rebalance the international freight road transport in Europe between a dominant Centre-East and a developing Centre-Mediterranean.

**Keywords** — *International Road Freight Transport, Germany, the Netherlands, Driver Costs*

The year 2007 and 2008 have been in France a full one in terms of studies, debates and propositions, in order to understand, accompany and relaunch international road freight transport in France, in particular as far as its engagement towards international markets is concerned, one that has been undergoing a downfall these last few years. Within the framework of the actions undertaken by the Conseil d'Analyse Stratégique ([www.strategie.gouv.fr](http://www.strategie.gouv.fr)), many reports have been published (9 reports at all that is to say 875 pages !) : they offer a full analysis of road freight transport in France but also internationally. The synthesis presented by Claude Abraham and his team – “For an ongoing regulation of road freight transport”<sup>2</sup> – and the reports of the different working groups<sup>3</sup> have been going through a wide consultation of all actors and show the need to compare the French situation with that of our European partners<sup>4</sup> in order to learn a lesson for the French transporters.

Within the framework of market intelligence missions and prospective analysis of the sector led by the Comité National Routier (CNR) some investigations have been undertaken in 2007-2008 on road freight transport and driving costs in Germany and Holland by the author, directed by Alexis Giret (CNR). This article proposes a synthesis of those two studies.

## METHODOLOGY AND FRENCH SITUATION

The study's methodology relies on a series of meetings/discussion led among road freight transport professionals (around 10 companies by country in more than 3 different regions for every country) but also

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<sup>2</sup> [http://www.strategie.gouv.fr/article.php3?id\\_article=838](http://www.strategie.gouv.fr/article.php3?id_article=838)

<sup>3</sup> « Développement, compétitivité, et emploi » ; chairman : M. Maurice Bernadet « L'acceptabilité sociale des poids lourds » ; chairman : M. Jean-Noël Chapulut « Les relations et les évolutions sociales » ; chairman : M. Georges Dobias « Transport routier de marchandises et gaz à effet de serre » ; chairman : M. Michel Savy

<sup>4</sup> Germany, as France does, has a good knowledge of the sector through the mission of market analysis of the B.A.G. (Bundesamt für Güterverkehr, Cologne). As expressed in a meeting by the Dutch Ministry of Transport, The Netherlands have a strong liberal culture and then few interests of markets analysis of private companies, for example in the transport sector. Some statistics of the sector for example are managed by NEA, a private company. TLN (Transport Logistic Netherlands, the professional association of Dutch Road Haulage) is a key actor too, for statistics for instance.

among professional organizations, trade unions, the university community and public institutions (Ministry of Transport). Statistics have been obtained among appropriate organizations, public ones in Germany (BAG - Federal Office for Freight Transport, or professionals road haulage associations (BGL, DLSV in Germany and TLN in Holland) or private/semi private ones in Holland working for the Dutch Transport Cabinet (NEA, NIWO). Costs assessments are a synthesis of crossed-information (BGL information), average values and estimates for Germany and panel results (NEA information) for Holland.

The starting point of the interest of professionals and French public institutions in the study of international road freight transport in Germany and Holland originates in the worrying observation in France of a decrease of French companies' market share in international road freight transport. In 2007, the French international road freight transport has decreased by 3,2 % in t.km (27,2 billion t.km) following a stabilisation noticed in 2006. In tonnes, the decline is 1,4 % by 2007/2006. Cabotage of French companies is also declining by around 24 % in 2007 ! This lack of competitiveness is part of a long trend : while, between 2000 and 2004, international exchanges between France and its 15 European Union's partners have increased by 17%, French transport companies has undergone a drop by 17% [40]. This drop can be explained partly by the decreasing share of French transporters in French international exchanges. French transporters have lost 3 points in market shares every year, dropping from 35,9% in 2000 to 25,5% in 2004. The increase in imports, for which French transporters have found it difficult to position themselves, is acting against French transporters. Despite a moderate increase in exchanges with Germany (+9%) which explains more than a third of the decrease of French transporters [40], French transporters' market share dropped by 12 points and German transporters are reinforcing their position as well as third parties (among which Dutch transporters) who have seen their activities progress by 50% since 2000 [40]. This situation is to be seen on the field specifically in Germany and can be partly explained with the introduction in 2005 in Germany of a pricing policy for the use of motorway infrastructure which has induced an increase in transport costs for French transporters and more particularly when return is an "empty" one. This factor has thus been well identified by the German authorities of the sector in its annual report : since the introduction of toll on motorways (2005), the annual report 2005 of the Federal Freight Road Transport Office [2, p. 13] is expressing that French companies are less present in Germany which gives German transporters more development opportunities<sup>5</sup>.

The screening of German and Dutch long distance freight road transport markets is very interesting in terms of their engagement at the heart of Europe in a hard competition with the European Union's New Member States. It is thus interesting to see how in both countries a whole sector, well organized and structured (in terms of legislation and socially), has reacted to this external impact. Commercially speaking these newcomers show a hyperdynamism, as we will see.

Focused on its internal market, the road freight transport in France seemed protected from "big manoeuvres" developing today in the East and South (Maghreb) but this fact is no longer true : French road freight transport is now confronted with **a double compression from both East (Germany, The Netherlands, East Europe) and South (Spain)** on the international market but also as far as national transportation is concerned when limits on "cabotage" will be abandoned. Moreover, this compression is far from being a static one and thus, it is in the framework of both an eastern and southern compression that the French freight road transport should be studied.

This situation could legitimately lead us to question the existence of French long distance road freight transport in the long term. Which strategic direction should we impulse to take advantage of the Europeanization of road freight transport on the European continent?

- Network strategies like suggested by German middle-sized companies
- Concentration and search for a critical mass around big road/rail/sea intermodal groups
- Withdrawal towards market niches
- Specialization in more profitable high quality and standards transports

<sup>5</sup> « Eine positive Entwicklung der Beförderungsentgelte sahen deutsche Transportunternehmen im ausgehenden Verkehr nach Frankreich, da es auf dieser Relation seit der Mauteinführung in Deutschland zu einer Laderaumverknappung gekommen war. Französische Transportunternehmen engagierten sich seitdem in geringerem Maß im Verkehr mit Deutschland. Problematisch waren für in diesem Bereich tätige deutsche Unternehmen die deutlich niedrigeren Beförderungsentgelte für Rückladungen aus Frankreich und die Tatsache, dass französische Auftraggeber die Zahlung der deutschen Maut in vielen Fällen grundsätzlich ablehnen. » [2]

- Closeness to a requalified and modern harbour (Holland)

or what we recommend: first a merging with Dutch and German companies in a European winner-winner perspective, taking into account the necessity of protecting competition, and, in a second best solution, a quick setting up of subsidiaries in Morocco or in Southern Spain in order to segment one's global transport supply (low cost/niches/high-rank) and thus rebalance the Center-East stream with a South-East powers... A Centre-Mediterranean answer to a freight road transport critical mass moving towards the Centre-East.

### **AT THE CENTRE OF EUROPE: A GERMAN ECONOMY FULLY EXPORTING AND A HARBOUR FOR EUROPE, ROTTERDAM**

Leaving aside the current crisis linked with petrol prices (july 2008) and financial market (september-october 2008), the road freight transport sector is not feeling to bad at the centre of Europe and enables Holland and Germany to position themselves as leaders in this field (table 1) for three fundamental reasons : a real dynamism of the German economy towards exports these last few months, the large outsourcing of subsidies and plants in East Europe linked with the new process of "Bazar Economy" described by H.-W. Sinn which imply a lot of transport between all the plants and subsidiaries all over Europe and the world, and a very profitable industrial worldwide positioning (success of a the famous structure of middle size companies likely to exports widely) and, for Holland, predominance of a great harbour for European inward and outward flows, this harbour being very closely connected with the German industrial structure. In the field of freight transport, the completion in 2006 of the freight railroads "Betuwelinie" between Rotterdam and Germany is considered essential.

TABLE 1 : ROAD FREIGHT TRANSPORT IN FRANCE, GERMANY AND THE NETHERLANDS IN 2004/2005

	France (2005)	Germany (2004)	The Netherlands (2005)	in...
T.km road freight transport on national territory	205	<b>384</b>	84	Billion t.km
- from national companies	177	267	32	Billion t.km
National companies in international t.km	<b>28</b>	71	<b>52</b>	Billion t.km
T.km freight rail transport	41	86	5	Billion t.km
T.km watervay	9	64	42	Billion t.km
Number of companies	36 000	48 500	12 000	
Trucks	185 500	345 500	77 500	(more than 3.5 t.)

Source : Alexis Giret and Laurent Guihéry, Synthesis Study CNR Europe, march 2007

For Germany, road freight transport is leading in Europe (table 1) which is easy to understand with the very central location of Germany in Europe between West and East. The reason for this are multiple but the main factor is the dynamic structure of middle size companies ("*Mittelstandunternehmen*") typical of German industrial and service oriented sector. These companies employ 72 % of the 22 millions employees and are making 50 % of investment. German road freight transport is twice the French sector (see table 1) and is growing quite well the last years (lack of drivers for the shipping of presents for Christmas 2006) like in Holland. Transport for third parties is important but some companies are thinking of "re-nationalizing" transport operation (own account) to keep 100 % reliability, punctuality and full efficiency of transport operations, which is in Germany presented as a label : "transport made in Germany". This label is very

important for shippers working with just-in-time model of production. Sales of below 12 tons vehicles are booming because the new motorway toll implemented in 2005 do not take these vehicles into consideration.

German transport companies are organized in both way: a high proportion of family and small companies organized sometimes outside the system of collective labour, middle size companies organized on a European network, and large operators like Schenker. Like in the Netherlands, the structures of companies in Germany is based on a dual system following the model of “insider”(protected / collective labour agreement) / “outsider model” (small companies, high flexibility and reactivity, lack of job security).

Costs in Germany are higher than those corresponding in France but this is changing rapidly : trucks are 10 % more expensive than in France, gasoline more expensive (+6,6 %, data CNR), indirect taxes (“*droits d’accises*”) higher up to 20 %, higher cost of insurance, toll pricing on motorway of around 0,20 cents euro / km since the 1 January 2005 (increased in January 2009) but this new costs was transferred on the shippers. Truck involvement is around 130 000 km/year more than 120 000 km reported in France (CNR). Wages are ruled by a labor agreement negotiated at the Länder level which implies disparities between East and West Länder. It can be noticed that “low cost” transport companies are existing in East Germany facing directly East European competition. East German drivers can then be paid 30 % less than in the West when labour agreements are applied which is not the case every time. The daily rate in Thüringen is 6,14 € one hour without length of service. West German transport operators are then mainly focused on “high quality transport” with high profitability and are likely to outsource transport operations in their East European or East German subsidiaries. Comparing productivities and wages of drivers, there are few differences between Germany and France ... but a German driver seems to drive 22 % more than a French one by using a more “company friendly way of driving” (few time of disposal, switching mainly between time of rest and time of driving). Following strictly European regulations and working for a flat rate imply a maximal management of driving time which is one of the lessons to draw of the competitive advantages of German and Dutch drivers.

Concerning Netherlands, road freight transport is growing rapidly in NL with 7% growth each year in average. The Dutch Ministry of Transport is expecting a growth of 20 % - 30 % by 2020. 12 000 companies are involved with 80 % specialized on international transport (70 % transport for others). The Dutch are very specialized in international transport with more t.km in international transport than in national transport ! The international road freight transport in Holland is then twice the French one : Dutch operators carry 57 % of their exports like France for 15 years but Dutch operators are also leading in imports (52 % !), which is surprising ! More than Germany, the Netherlands are THE reference in terms of hyper-productivity in road freight transport : linked with the framework of the “polder model” (liberal way of life, entrepreneurs spirit, consensus, negotiation, compromises, flexi-security social system, dual system following the model of “insider”(protected / collective labour agreement) / “outsider model” (small companies, high flexibility and reactivity, lack of job security)) and far away from public interventionism, the labor relations in Dutch road freight transport are managed by a system of collective and autonomous labour agreement (see TLN and the 112 pages of their very precise labour convention 2007). The daily rate is 9€84 while beginning to work till 12€54 after six years of work in the same company (value October 2006) : 40 hours a week ; +30 % if overtime ; + 50 % if worked on Saturday ; +100 % if work on Sunday.

Operating costs are higher : buying a truck seems to be a little bit more expensive than in France, insurance are 50 % higher, gasoline and maintaining / repairing are around 5 % less expensive. As expressed in the table 2, driving cost are widely higher and are one of the higher in Europe and this positive point for employers are compatible with a leading position of Dutch operators in Europe .

To sum up, it seems that the Netherlands have set up a winner – winner model :

- Wages (50 % more than a French driver in average)
- Competitiveness (despite an hourly cost 8 % higher than a French driver specialized in international road freight transport).
- Large turnover and jobs available: lack of drivers is a reality.

The success of the Dutch transport operator in international operation is then based on a high volume of work (trucks are then driving till 150 000 or 180 000 km/year and a high flexibility of the labour organisation of drivers, which lead to a competitive advantages of Dutch operators on the European market. Drivers are, in Germany and in The Netherlands, maybe more implicated in the success of the company by choosing “driving

time” position or “rest time” position more than “*disponibility time*” on the tachograph. The yearly working time is around 213 days like in France. But differences are obvious in the organisation of companies looking for productivity gains, management of tours and efficient allocation of drivers : normal day of work in this sector can reach 11 hours a day, weekly working time near 55 hours (reaching 60 hours in certain cases),... On this point, due to the central position of Rotterdam Harbour in European Transport facilities, the European Commission has given an additional delay since march 2010 (5 years more) to transfer the European Guideline 2002/15 (limit of working time of freight road driver to 48 hours a week in average).

## HYPER PRODUCTIVITY OF DUTCH AND GERMAN COMPANIES

In both Germany and The Netherlands, transport operators are hyper productive and put gains of productivity at the centre of their business management. For middle size companies, they develop networks of companies for achieving a better critical weight and a better visibility. They get more concentrated too. Table 2 is expressing this hyper productivity of German and Dutch operators by showing a compared analysis of driver costs in four European countries. Methodology of the study was introduced in introduction of this paper. For Poland and France, data are coming from the CNR. East Germany can appear as a “low cost region” in Western Europe facing directly East European competitors but are full part of the famous German label of “Transport made in Germany”. Western German companies are then outsourcing easily unprofitable or complicated transport operations to their East German subsidiaries for the benefit of both shippers and transport companies, both in West (keep competitiveness) and in East (having some work in a difficult economic framework).

TABLE 2 : MAIN RESULTS OF THE STUDY ON DRIVING COSTS IN GERMANY AND THE NETHERLANDS, IN COMPARISON WITH FRANCE AND POLAND (2006)

Estimations	Unit	France : study CNR	Germany : West Länder (average)	Germany : West Länder (maximum)	Germany : East Länder (minimum)	Netherlands (Source : NEA data international to France) and own adjustments ;	Poland (estimation 2006 CNR ; rapid growth)
Wages (with overtime and bonus)	€/ month	2173	2734	2967	1718	3223	from 820 to 1,360
Employers charges	%	36 (Fillon support deducted)	25	25	25	36	22.57
Travelling expenses in average by day	€/day	38-40 Average with 50 % international	20	20	20	40 international -7 national	from 25 to 40
Total yearly cost	€/ year	44 173	45 463	48 960	30 425	55 132	20 000
Weekly working time	Hours / week	49,6	56,5	56,5	56,5	55	56,5
Number of working weeks by year	Week / year	42	42	42	44	43	45 to 46
Yearly working time	Hours / year	2100	2373	2373	2486	2343	2500
Yearly driving time	Hours / year	1554	1890	1890	1980	1917	2015
Cost of one hour of work	€/ hour	21	19,2	20,6	12,2	23,5	8
Cost of one driving hour	€/ hour	28,4	24,1	25,9	15,4	28,8	10
Base 100 France on the driving hour		100	85	91	54	101	35

Source : Studies CNR Europe, data CNR, own calculations and cross comparisons, firms and univ. interviews

## **WHY LOOKING TO ROAD FREIGHT TRANSPORT IN GERMANY AND THE NETHERLANDS: WHICH RECOMMENDATIONS?**

Germany and The Netherlands are leading in international road freight transport in Europe today and are facing a strong competition from East European countries. They are pioneers in reaction and strategies developed facing new member's states and French operators can then learn from them.

Objectives are, like the history of the European Union Integration process, to balance benefits and risks among European nations in a long term process of mutual convergence. If we consider that the competency of international road freight transport is a key function of each nation states and then cannot disappear in France (no total specialization on the European level in the transport sector is likely to emerge - this assumption has to be investigated -, then we can propose some recommendations for French transport companies and public authorities.

Road freight transport in Germany and Holland is dynamic and successful since the joining of the New Member States in the European Union (opportunities), even if the competition is becoming stronger and profitability low (or negative like in Holland in average). Companies in both countries are facing a lack of drivers. "Cabotage" is, in a short future, challenging the future of French road freight transport, especially with Romania and Bulgaria. Ukraine, Turkey and Russia are also in a middle term perspective also formidable partner.

Facing this new European environment, German and Dutch companies have developed interesting strategies:

- Following of industrial companies in the outsourcing of production process in East Europe (especially Germany) ; Transport and logistic subsidiaries set up in East Germany (driving costs between 20 and 30 % less expensive) or in East Europe with merging with local operators (driving cost inferior to 40 % following a study of the BGL and the German Transport Ministry).
- Productivity gains if possible
- In Germany: decrease of average personal costs, maybe driving costs but difficult to show evidence on this point. Germany is the only country in Europe that has experienced an average decrease in wages the last 5 years (decrease of real wages of 0,8 % the last 8 years (2000-2008, Source : foundation Hans Böckler, Les Echos, 18.09.2008 ). More and more workers (maybe drivers?) in Germany are not integrated in collective labour conventions, which have an impact on competitiveness. This trend is considered as "competitive disinflation" which has an impact on restoring cost-competitiveness of Germany the last years. This model is less transferable to France for socio-historical raisons (strong trade unions, lack of confidence between social partners,...).
- Networking of medium size operators to increase the critical mass and get more visibility; strategy to be developed with French operators; outsourcing of non profitable transport to small operators or East European partners, like in Germany.
- Better connection with ports (example of Rotterdam and European Distribution Center) ; balance development with other European ports to be investigated, especially with congestion issues in Rotterdam Harbour.
- Specialisation in high quality transport as the German operators do : reliability, punctuality, services (logistic, packaging,...), know how ; "niche" market ; label quality transport (like the famous "transport made in Germany").

Concerning the French transport operators, the development of European International Road Freight Transport implies a rapid and strategic reaction : if we consider and accept the process of European integration process as a complicated balance and trade-off between nation states in a winner – winner game – this was the case for the last 50 years of European integration, we cannot accept both in Germany and in The Netherlands the disappearance of the French international road freight transport. Solutions has to be found in the merging of French operators with German and Dutch operators in a winner – winner model : giving access to south European or north African markets for central and north European operators and increase of critical weight for accessing East European markets for both French and Dutch / German operators. In a second best solution, if merging is unlikely to appear, French operators would have interests to "move South", by setting up

subsidiaries in North Africa (Morocco). If this solution is likely to boost, on a short term perspective, the competitiveness of French international road freight companies, the impact of such strategies on the current European integration process (political integration) is difficult to assess.

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# **Chapter 12**

Transport and Land Use



## LAND RENT AND NEW TRANSPORT INFRASTRUCTURE: HOW TO MANAGE THIS RELATIONSHIP?

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**Abstract** — *This paper discusses the relationship between land rent and new transport infrastructure, and analyses the problems of social structure and distribution of income that can arise. The building of a new transport infrastructure, increasing the accessibility of the area and the level of mobility, can result in the increase in the value of land in that area. This is also tightly linked to building constraints on the area, because they raise the scarcity of land that is an element of land rent. So, if accessibility increases and if there are building constraints, also land rent will rise. This land rent can be transferred into the prices of houses and buildings, and in turn of goods and services, which are in the ownership of individuals and firms. This raises the issue of social distribution: while the transport infrastructure is paid for by all taxpayers, one important benefit, land rent, is captured only by a limited number of owners (it can be also the total of owners). Is it possible to avoid this and how? There are, at least, two ways. First, the capture of land rent by general financing options. This practice, common in USA, takes part of the benefits arising from the building of infrastructure to finance it. Second, the removal or reduction of building constraints on the land involved. Rent, among other factors, is a function of the scarcity of land and building constraints help establish scarcity of land. If new building land becomes available, total rent decreases.*

*In this paper we examine the connection between the building of a transport infrastructure and the land rent that it creates, and we try to explore two solutions to manage the issues of social distribution that may arise.*

**Keywords** — *building constraints, fiscal instruments, transport infrastructure, land rent, social distribution, rent skimming.*

### INTRODUCTION: LAND RENT

The relationship between land rent and transport infrastructure is tightly established.

Land rent is due to two conditions: first the scarcity of the resource “land” and second the difficulty to substitute this resource with another one. So, it is possible to explain land rent as income that a land owner receives from his land thanks to these features of scarcity and uniqueness. This latter feature is a function also of its accessibility and so, of the infrastructure level in that area.

This relationship is clearer when a new transport infrastructure is built: it increases the mobility level of the area and so its accessibility. This aspect enhances the real estate price (accessibility is a component to establish the real estate price) that raise the level of land rent. The new rent can be transferred on to the price of house and building and, in turn, of goods and services.

The consequences of these relationships can raise problems of social structure and distribution of income: while the transport infrastructure is paid for by all taxpayers, one important benefit, land rent, is captured only by a limited number of owners (it can be also the total of owners).

Is it possible to avoid this and how? There are, at least, two ways. First, the capture of land rent by an impact fee; and second, the removal or reduction of building constraints on the land involved.

### RENT SKIMMING

Land rent is linked to transport infrastructure: where once transport infrastructure is built, the level of rent of the building in the nearby area is raised, without any effort for the land owners.

Transport infrastructure is a public service for the community, and it seems incorrect that one of its benefits, the accessibility, is used to increase the value of some private goods or services.

How is it possible to distribute the benefits to the community? What can the public administrators do to recover part of land value increase linked to a new transport infrastructure?

One solution is the application of some type of financing options.

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## Land use policy

The aim of land use policies is the regulation of the use and transformation of land, and they involve all planning tools to do it. A section of these policies are the financing policies: they are dedicated to recover the new rent generated for the community and to finance infrastructures or public services.

These policies can be applied because the land owners have not paid “production costs” to have the increase of land value, but it has been given via a public action (the building of transport infrastructure).

There are different broad ways to skim this rent that depend on the type of partnerships. Below is reported a proposed list.

## Public - private partnership

The increase of new land rent is, as it already said, tightly linked to the building of new transport infrastructure and to the relative property development. High levels of mobility, due to new infrastructure, establish benefits to whoever lives in that area and, in the case of property development, to the promoters of the project.

Indeed, it seems lawful to apply a system of fees to skim the rent on the subjects, the property promoters, which enjoy the most advantages due to the location of the project. Often this practice is a public-private partnership between local administrators and property developers.

It is sometimes considered that those developers who obtain planning permission should be required to pay for the betterment generated by a planning system which limits land supply and thus concentrates land value. This value may then be captured by the lucky developer with planning permission. In view of this, it is legitimate to seek planning gain for local communities as an *ad hoc* local approach to collecting betterment. Extracting such gain from developers is also attractive to local authorities and the infrastructure providers as a way of obtaining contributions to general and specific funds over and above those needed to cope with the specific impacts of project (Healey P., Purdue M., Ennis F., 1995).

There is a risk that this proliferation of exactions based on property development is in large part due to today's crisis in public finance. Many sources of funding for public infrastructure and services have not kept pace with costs. It is possible that local authority use these tools to find resources to fund new public infrastructures or services, in order to accommodate growth (Deakin E., 1996).

Despite this fact, the fee is a good instrument to skim the rent due to new property development, and it is the simplest way to capture the economic benefits concerning the building of new transport infrastructure.

## Tools

There are many ways to apply this practice, and depend on the legal authority granted to local jurisdictions by the various states. Generally there are, at least, four principal tools to skim the rent:

- Proffers;
- Impact fees;
- Benefit assessment;
- Dedicated taxes.

*Proffers* are a premise to have, from public administrator, a building permission. They involve some actions that property developer must to do to have the permit. These actions are in relation to the dimension of impact of the project, and they can consist of a new road, new public facilities (school, hospital, etc.), etc.

*Impact fees* were pioneered in United State in 1960. They are fees, paid from land owners, to cover the costs of services and infrastructures in proportion to the project. These fees are used to cover the social costs to the new project and they are considered a reimbursement, from property developer, to compensate the negative impacts of the project. Although development impact fees intend to transfer the burden of infrastructure provision to the developer, some evidence suggests that the cost of infrastructure gets shifted to new residents of the community and that a new homebuyer ultimately absorbs the cost. It has also been suggested that the existing community pays a portion of the cost through inflated prices on existing housing and land.

Development impact fees have emerged as away to pass the cost of new infrastructure to the development community.

The fees can be used to pay for new roads, extending water and sewer lines, and schools, among other things. The city put in the impact fees to pass this additional cost on to the new homeowners and businesses that wanted to develop in this area.

They are directly tied to planning in that they are used to help finance a local capital improvement program that itself implements overall community planning objectives.

Impact fees are used in areas linked to new property development where new infrastructures are built.

There are two other types of impact fees:

- linkage fees. These fees finance social infrastructure to meet new social needs linked to new property development.
- mitigation fees. These fees concern environment impacts due to new property development, and they are used to refund the negative impact on community.

Impact fees are subject at some criticisms.

The first blame these fees for damaging the local economy, because some property developers can move their projects to places where there are not any fees. The second considers impact fees to increase the price of houses. It is possible that property developers add to house prices the part of fees that they should pay themselves. Indeed, the fees are transferred to new owners that pay, for the same house, more costs.

Often these criticisms are considered unwarranted and unrealistic, especially when impact fees are used to finance infrastructure necessary to community.

Today, impact fees have become a popularly used method. In USA about 60% of all cities with over 25,000 residents along with 40% of metropolitan counties use impact fees on new developments for public services or infrastructure. In some cities or states such as Florida, 90% of communities use impact fees. Twenty six states have implemented the use of impact fees in the western portion of the country, along the Atlantic coast, and within the Great Lakes region.

*Benefit Assessment Districts (BAD)* are considered a tax that local administrators charge property developers for the benefits introduced with a new project. The fees concern the benefits of new infrastructure and they are proportional to the services offered.

They are commonly characterized as geographical areas (*Business Improvement District BID*) within which fees or taxes are collected to fund capital investments or special services that clearly benefit properties within the district. The distinctive feature of special assessment districts is the very close and visible tie between the facility constructed or maintained and those who benefit from and pay for it.

Benefit Assessment Districts are attractive for several reasons. They shift the burden of infrastructure finance from the general public to properties receiving direct benefit, while avoiding the short-term time horizon of purely private infrastructure provision.

BAD is often used to cover the costs of a new public transport lines in an area, through the fees on beneficiary (Newport Partners LLD, Davidsonville MD, 2007).

One important experience of BAD is been applied in Los Angeles to finance the first part of red line of the tube. The costs of the whole project is respected in 1,4 million dollars and, in the 1985, the "Southern California Rapid Transit District" (RTD) has established a BAD to obtain and refund a funding of 130 million of that (about the 9%). The BAD is been funded to the owners of offices, shops, hotels and other business' activities localized in the areas around the main station of the tube. The value of fee is depended to the different planning destination, to the distance of the building to the station and to the cost of the infrastructure in that area.

*Dedicated taxes* are particular fees applied to some activities or people to achieve one share purpose. The essential argument is based on the principle that who receive a service should pay for it. In fact, on the theory, people will be more willing to pay if their money is dedicated to programs they want or need.

It is important that the public service (school, health, police, etc.) remain to the public responsibility, and only a extraordinary services must to be finance with a dedicated taxes. These taxes are use also to assure a minimum level of support and continuity of funding for specific projects or services.

Dedicated taxes have also some criticism. Main risk is about the possibility that public administrations use always these taxes to finance a project and this may become a only way. Then it can increase the difficulty of

adapting budgets to changing economic and social conditions because part of budget is fixed and assigned for some years to a determinate project.

One infrastructure funded with a dedicated tax is the Bay Area Rapid Transit District (BART) of San Francisco.

All these tools are often used to compensate a negative impact, rather than to decrease the impact itself. This can be a problem when this fee, linked to new property development, is overlapped with other tools for the mitigation of the negative impacts of the project.

## BUILDING CONSTRAINTS

Zoning is a system of land-use regulation.

It is a practice of designating permitted uses of land based on mapped zones which separate one set of land uses from another. One task of planners is to set clearly in which portion of territory is possible to build. This implies building constraints to manage the territory and to narrow the building; constraints are able to render land “scarce” and, as a consequence, to create differential rent. Camagni notes that land is a scarce resource and it is hardly to expend. For this reason it is appoint to have a potential extra-remuneration (Camagni R., 2000, pag. 184).

In this setting, zoning has an influence on the land rent. Land rent is linked to the role of the public administrator, that can establish residential zoning (through the city plan) and the location of new transport infrastructure (which improve the accessibility), and it is influenced by the attractiveness of the area (through urbanization works, bigger services and urban quality).

If, for example, the public authority decides to locate an infrastructural project in a specific area (due to a decrease of the building constraints in that area), there will be a benefits<sup>2</sup> to that territory, and so an increase in land rent (Camagni R., Capello R., 2005).

Why can the decrease of building constraints resolve the problem of social distribution?

As it already said, building constraints help establish scarcity of land, and this characteristic increases land rent. This rent can be transferred into the prices of houses and buildings, which became more expensive. In this way there is price discrimination, because some people cannot pay for the same building or services.

Moreover, building constraints are more binding in a central location (where there are economies of scale), and so the higher prices are localized in a central location. So, people with a lower willingness to pay for those goods (houses) must to move themselves to where the price (and land rent) is lower, and the city is expanding in space toward marginal areas: there is an increase in transport costs and a sprawl phenomenon. In these conditions, elements of the community are discriminated and there is an incorrect income distribution.

If all activities try to concentrate in central locations, where both accessibility and economies of scale are maximum, only the price of land (= rent) counter-weights this tendency. But the price of land, as far as total saturation (skyscrapers of Shanghai scale) is not achieved, depends on its man-made scarcity, and so, on building constraints.

If there is a removal or reduction of building constraints on the land involved and if new building land becomes available, total rent decreases and:

- the land owners do not enjoy economic benefits due to additional rent, only to have land in a particular location (for example, near new transport infrastructure);
- anyone can build in the same way and there is not different land;
- there is not sprawl induced by the scarcity of land;
- there are also efficiency gains, as by definition there are economic benefits stemming from any reduction of constraints;
- there is a transfer of benefits from land owners to all community;
- it is possible to change a planning system that could prefer some subjects rather than others, sometimes with a blurry mechanism of building constraints assignment.

Reducing building constraints will generate a reduction both of transport costs and externalities (and more efficient non-subsidized public transport), and distribution benefits (less rent).

<sup>2</sup> For example larger accessibility in the city, larger urban quality, larger environmental quality.

The tie between land rent and building constraints is summarized as follow:

- planning, through the definition of building constraints on the territory and the location of new transport infrastructure or new public transport system, can influence the increase of rent and the economic benefits concerning this additional rent. This supplementary rent will be high in a central area, thanks the scarcity and uniqueness of “its” land;
- rent weighs upon the social distribution of income, favouring land owners and giving to them benefits without any effort.

If building constraints, assigned to different land with an urban plan, can favour conditions to rise land rent (already strictly linked to economies of scale and economies of agglomeration), then it is possible to hypothesize that without building constraints determined a priori on a plan, the specific rent will be equal to zero. In this situation, the additional economic benefits, owing to the constraint, could disappear. Instead of these, it will be competition that could distribute the benefit to all community.

If it hypothesized, in a last case, an abstract city collapsed in one point, then it will be possible to notice that, without constraints, there could be not land rent and all the construction will be built in a place with higher economies of scale.

In theory, this is the best solution to have a better social distribution. In reality, it is very difficult to apply this, because the entire community would be built near the area with most economies of scale (the limit case is an oversize skyscraper).

Realistic contexts are different and they are obviously within a standard urban circular scheme and it is indeed likely that building constraints tend to be relaxed in more external and less dense areas.

There are no doubts that policy recommendations have to favour the eliminating building constraints as close as possible to the central area (where there are the most economies of scale and the land is more attractive), because when building constraints are lowered there are positive impacts on income distribution.

## CONCLUSION

The tools to skim the rent and the will to remove building constraints follow the direction to reduce the additional rent for a better social and income distribution; each of these have different characteristics but both pursue one same aim<sup>3</sup>. Therefore, is it possible to join some features of fiscal instruments and planning measures in an integrated system? In this way, it establishes only one articulate structure with one shared purpose. How can it be organized?

Observing that it is not possible to remove completely building constraints and that rent will always be created, the solution is a mechanism that gives rise to rent but “under control”. In other words, with a specific distribution of building constraints targeted, it gives the possibility to use benefits concerning high accessibility (that lead to benefits on public transport system and environment) but, at the same time, through the fiscal system, it is possible to distribute these benefits to the community.

The accessibility is influenced by the location of new transport infrastructure or new public transport on territory, and it is, as already said, one function of land rent. It has got special potential that, if used in better way, can exploit the benefits of the economies of scale in central area and so can reduce private mobility (in favour of the environment). Paradoxically, it should start a relation in which if accessibility increases, also the level of building on the territory increases in a proportional way, within the limits of the zoning in force. In this way, can become a further instrument to incentivise the development of areas with high levels of accessibility (Franceschini S., 2008).

The solution could be including two steps:

- building constraints should be calculated to incentivise the proximity at points, on territory, with higher accessibility. In this way, development tends to evolve near central locations (where the most economies of scale are located) across public transport structure, and so it can disincentive private mobility and the sprawl. Planning should correlate possibilities and costs of urban expansion with the accessibility of the territory;

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<sup>3</sup> Fiscal instruments and removal of building constraints are equivalent for distribution issues, but they are very different for efficiency issues: while the fees concern the economic benefits of the new transport infrastructure but they keep the scarcity of land, the removal of building constraints eliminate also the scarcity of land. The first solution takes care of effects of land rent concerning new transport infrastructure, while the second one aims to prevent his formation.

- benefits generated with a central location (additional rent) must be captured with fiscal instruments and, later on, spread to the whole community.

The results of these actions (to apply in a unique system) are a concentration of new activities, building and services near the new node of transport, that:

- provide demand for transport where there is supply. In this way, there will be a (partial) reduction<sup>4</sup> of private mobility and a betterment of the environmental<sup>5</sup>;
- through increasing accessibility, land rent arises and it is possible to design a fiscal system to capture the benefits deriving from the increase in property value.

This solution is possible only in an urban and dense location, where public transport system is efficiency and competitive with network of road transport. With public transport system, the accessibility, and the rent that is generated, is concentrated in some points, which can be controlled.

In extra-urban location, where the activities and the buildings are spread in the territory, public transport system is not useful at the necessity of movement, because it is not flexible in the territory (it has got fix timetable and fix route). Therefore the network of road transport, that is “capillary”, is winning. The accessibility is spread and so the rent is less and most distributed. In this case the fiscal instruments cannot use, because there are not essential requirements (high rent in a specific location) and lack some definite subjects to apply the mechanism (community is scatter in the territory): the system cannot controlled.

The mix of instruments in use today follow different directions and the fiscal field and planning field often do not converse. This system does not ensure a rational planning on territory, because it does not:

- incentivise a neat organization of territory;
- exploit the capability of accessibility;
- use the benefits of transport infrastructure.

Moreover, fiscal instruments do not give a correct signal and, often, their aims are obfuscated to the necessity of local authority to have a supplement voice of budget.

The correct signal of the measures is an essential condition to the fiscal system.

This paper wants to be a little step to increase awareness towards these issues and to start the well-known integration between transport and planning. Indeed, from many years a mixing of this know-how has been discussed theoretically, but there are not significant results in practice. Often it is difficult discover a concrete and coherent application to do that. Today, the scientific debate is in agreement on the theoretical dynamic, but it is missing the instruments to apply the integration and guidelines that address public authority towards attainment of this policies.

The aim of this paper is to focus attention on these issues in an urban area and try to give a “key” to read the conflict in a different, but concrete, way.

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<sup>4</sup> The level of reduction is in function of the type of transport infrastructure: if it is a public service the reduction is total (the user don't catch a private transport to move himself).

<sup>5</sup> The betterments for the environment are linked with less movement to arrive until the new transport infrastructure. If the infrastructure is a public service, the betterment involve all the movement.



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# EFFECTS OF PAVEMENT CHARACTERISTICS ON THE TRAFFIC NOISE LEVELS

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**Abstract** — In recent decades, noise pollution has become a major concern around the world due to industrialization and increased motorization causing a threat to human well-being. Road traffic is the most prevalent source of noise emissions by transportation. Tire/pavement noise is a major contributor to traffic noise at highway speeds. Tire/pavement noise is affected by different pavement properties. A study conducted in California measured the noise levels of different pavement types and the pavement characteristics affecting noise levels as measured by California On-Board Sound Intensity Method. Data was collected on dense graded asphalt concrete mixes (DGAC), conventional open graded mixes (OGAC), open graded rubberized asphalt concrete mixes (RAC-O), and gap graded rubberized asphalt concrete mixes (RAC-G). A total of 72 field pavement sections were included in the study, all of which were less than 8 years old at the time of the measurements. This paper evaluates the effects of pavement characteristics including the air void content, gradation properties, IRI, texture, pavement surface condition, and age on third-octave band frequency noise levels and identifies the pavement characteristics that would be more annoying to human ear.

**Keywords** — Flexible pavements, noise, pavement surface characteristics, tire/pavement noise

## INTRODUCTION

Noise pollution caused by industrialization and increased motorization is a growing concern to the public due to its effect on human well-being. It may have negative effects on health, productivity, and economics. Health consequences of noise pollution include hearing impairment, sleep disturbance, and cardiovascular effects while productivity consequences include interference with social behavior, performance loss, interference with speech communication, and annoyance [1]-[3]. The economic consequences of noise include property value loss in areas subject to noise, lower work performance of those affected by noise [4], and medical costs of improving the state of health of those affected by noise [5].

The adverse effects of noise on health, productivity, and economy have forced highway agencies to abate traffic noise levels. Quieter pavements have become an attractive option for minimizing the impacts of traffic noise levels in neighborhoods adjacent to highways. A noise reducing surface is defined as “a road surface which, when interacting with a rolling tire, influences vehicle noise in such a way as to cause at least 3dB(A) lower vehicle noise than obtained on conventional and most common road surfaces” [6]. Literature shows that open graded asphalt mixes can reduce the tire/pavement noise, and hence traffic noise compared to dense graded mixes [7]-[9].

Tire/pavement noise is affected by pavement surface characteristics such as texture, roughness, air void content, thickness, and age. Different pavement characteristics affect different frequency levels of the tire/pavement noise. The frequency content of sound is important since it was shown that human ear is more sensitive to sound in the frequency range between 1000 Hz and 3000 Hz [10] and annoyance increased as the high frequency component of the noise increased even though overall noise level stayed the same [11].

In the last decade, open graded mixes have been placed in California and other states, in part to benefit from their noise reducing properties. There is a need to better understand the long-term acoustic properties of pavements as well as the noise reduction provided by open graded mixes. The purpose of this study is to determine the noise levels of different types of asphalt pavement mixes at different ages and to identify the effects of pavement characteristics on the noise levels as well as to identify the pavement characteristics that would be more annoying to human ear.

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## METHODOLOGY

### Site Selection

This study presents the analysis of data collected over two years from 72 field pavement sections in California. The experimental design is a full factorial including four different asphalt pavement surface types, three different age categories, two traffic types, and two rainfall regions. There are some replicates in the factorial.

The four mix types include open graded asphalt concrete with conventional and polymer-modified binders (OGAC), open graded asphalt concrete with rubberized binder (RAC-O), rubberized gap graded asphalt concrete (RAC-G), and dense graded asphalt concrete with conventional and polymer-modified binders (DGAC). Age categories include less than a year old, one to four years old, and four to eight years old. Traffic type, based on California Department of Transportation (Caltrans) 2004 annual average daily traffic (AADT) data for highways and freeways (Caltrans 2004), was categorized as “high” if the AADT (two-way) is greater than 32,000 vehicles per day and was categorized as “low” otherwise. Rainfall is based on annual average rainfall in California from 1960-1990 obtained from CDIM software (PaveSys, 2004). The rainfall was categorized as “high” if average annual rainfall is greater than 620 mm (24.4 inches) and was categorized as “low” otherwise.

### Data Collection

In this study tire/pavement noise was measured by On-Board Sound Intensity (OBSI) method. In OBSI measurements two locations of the sound intensity probe are used: one is at the leading edge and the other at the trailing edge of the tire/pavement contact patch. The probe consists of two 25 mm phase-matched microphones spaced 16 mm apart and preamplifiers in a side-by-side configuration. A foam windscreen is placed over the microphones to reduce the wind noise. Signals from the two microphones are input to a two-channel real time analyzer. OBSI measurements are taken at 97 km/h. When that is not possible, an alternative speed of 58 km/h is used. The OBSI results measurements at 58 km/h were adjusted to their equivalent values at 97 km/h based on a field testing correlation study. Three replicate measurements are collected at each probe location, which are the results of consecutive passes with the instrumented vehicle on the 150 m sections selected for this study. Air and pavement temperatures are also recorded during OBSI measurements. Measurements were conducted using a Goodyear Aquatread III tire and Dodge Stratus car. The OBSI results are expressed in terms of A-weighted sound intensity levels, dB (A).

In addition to the OBSI measurements, data on the pavement characteristics were collected. Microtexture was measured using the British Pendulum Tester and the results expressed in terms of British Pendulum Numbers (BPN). Macrotexture was measured using a high sampling frequency laser profilometer on the instrumented vehicle used for the sound intensity measurements. Macrotexture results are reported in terms of Mean Profile Depth (MPD) and Root Mean Square (RMS). Roughness was measured with the inertial laser profiler and reported as International Roughness Index (IRI). Pavement condition surveys were conducted using the Caltrans Condition Survey Manual (version year 2000) on the 150 m segments. A total of twelve cores were also collected, 6 in the wheelpath and 6 between the wheelpath, at 25 m intervals from the selected pavement sections to determine the air void content and aggregate gradation. Air-void contents were calculated using the bulk specific gravity value obtained from CoreLok™ measurements and the theoretical maximum specific gravity value obtained according to ASTM D2041. After the asphalt from the core samples was burned off in an ignition oven, the aggregate gradation was obtained by sieve analysis according to ASTM C136 and ASTM C117. Thickness of the cores were also measured and recorded in the laboratory.

## DATA ANALYSIS

### Analysis of Overall Sound Intensity Levels

In this study, the effects of the following pavement variables were investigated: BPN, MPD, RMS, nominal maximum aggregate size (NMAS), coefficient of uniformity ( $C_u$ ), fineness modulus, air void content, permeability, mix type, IRI, surface thickness, pavement age, rubber inclusion, and pavement distresses on the sound intensity levels.

Figure 1 shows the variation of sound intensity levels of the OGAC, RAC-O, RAC-G and DGAC mixes in different age categories for the two years of data collection as Phase 1 and 2. It can be seen that sound

intensity values generally increase with age. It can also be seen that DGAC mixes have the highest sound intensity levels. RAC-G mixes are the quietest among all the mix types that are less than a year old, however they lose their noise reducing properties with time. Overall, open-graded mixes may reduce noise levels, on average 2 dB (A) compared to dense- and gap-graded mixes.

The effects of pavement characteristics on the OBSI levels were investigated using correlation analysis. OBSI was found to be positively correlated with IRI, age,  $C_u$ , surface layer thickness, and presence of transverse cracking and raveling and negatively correlated with mix type, air void content, and fineness modulus at 0.05 significance level. OBSI levels increase with increasing IRI, age,  $C_u$ , surface layer thickness, and presence of transverse cracking and raveling and decrease with increasing air void content and fineness modulus. Open graded mixes have lower noise levels compared to dense and gap graded mixes.

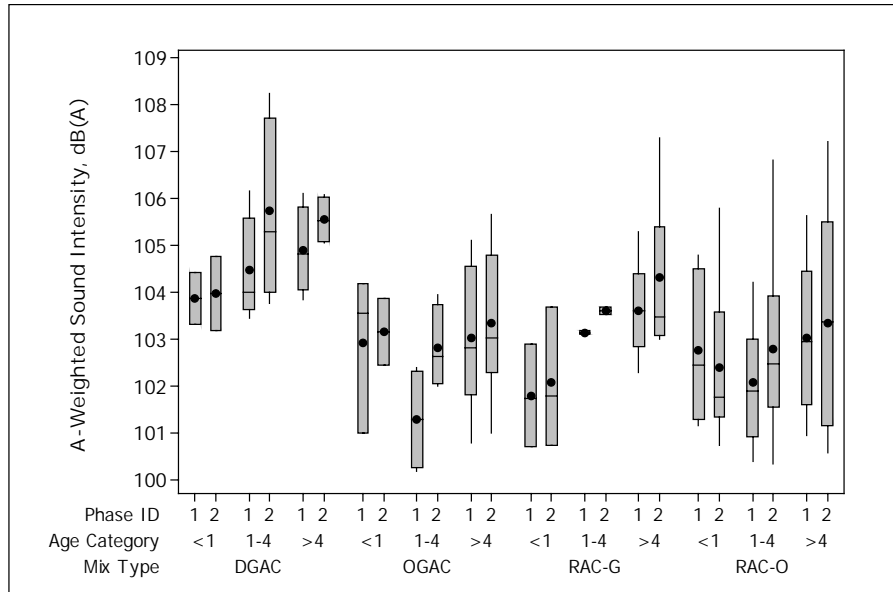


FIGURE 1.

Sound Intensity Levels for Different Mix Types at Different Ages

Figure 2 shows the sound intensity levels versus the air void content for different mix types. It can be seen that the sound intensity levels go down as the air void content increases for dense and gap graded mixes, while the noise levels of open graded mixes are insensitive to air void content for open graded mixes.

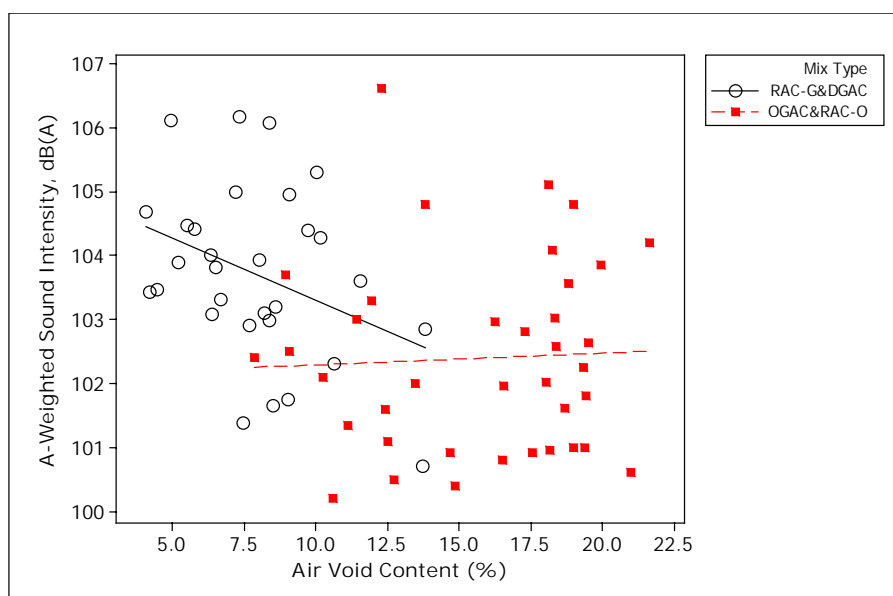


FIGURE 2.

Scatter Plot of A-weighted Sound Intensity Levels versus Air Void Content for Different Mix Types

Figure 3 shows the sound intensity levels versus the surface layer thickness for different mix types. Noise levels go down as the thickness increases for open graded mixes increase while the noise levels increase with increasing thicknesses for dense and gap graded mixes. Although the trend between the noise levels and thickness for open graded mixes is due to the four points, shown in the circle; it suggests that when the thickness is above 50 mm, thickness may have a noise reduction effect for open graded mixes.

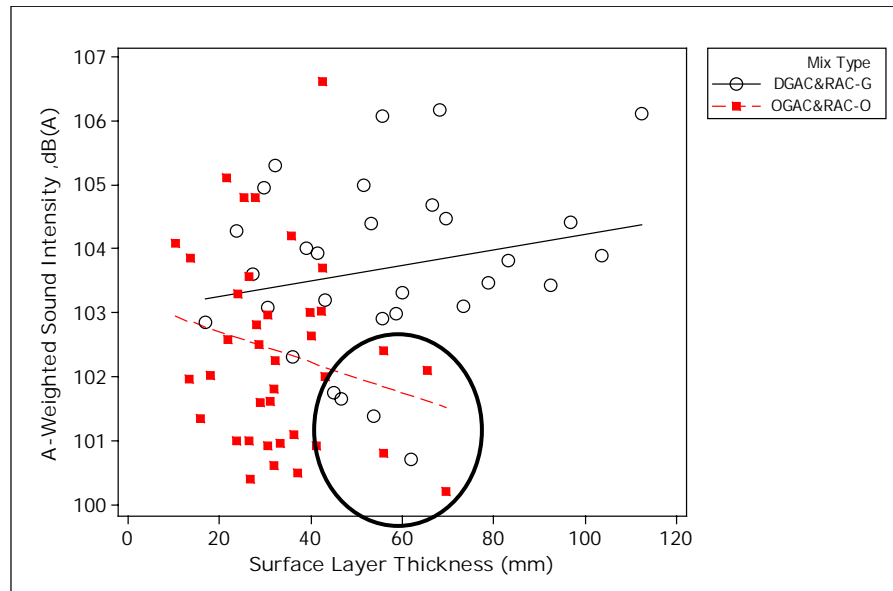


FIGURE 3.

Scatter Plot of A-weighted Sound Intensity Levels versus Surface Layer Thickness for Different Pavement Types

#### Frequency Analysis of Noise Levels

The effects of pavement characteristics on the noise levels at different frequencies were investigated using regression analyses. Separate single variable regressions were conducted for each frequency level, from 500 Hz to 5,000 Hz. shows the variables affecting the sound intensity levels at 5 % significance level for each frequency and their sign. The variables are shown in order from the one with the highest coefficient of determination to lowest coefficient of determination. A positive (+) sign indicates that increasing the value of the independent variable increases noise at the given frequency. For the categorical variables, a positive sign indicates that the variable coded as “1” increases the noise levels compared to the variable coded as “0.”

It can be seen that the 500 Hz and 630 Hz band frequencies are mainly affected by texture variables (MPD and RMS) while 800 Hz and 1000 Hz band frequencies are mainly affected by mix type (open graded mixes versus dense and gap graded mixes). For frequencies above 1000 Hz, air void content has the biggest effect on the noise levels. Increasing texture also reduces the noise levels at frequencies above 1,600 Hz. Since the human ear is more sensitive to high frequency noise and more annoyed with increasing noise levels at higher frequencies, open graded mixes which have higher air void content and texture may be perceived as quieter although the overall A-weighted noise levels are not significantly different than those of dense-graded mixes.

**TABLE 1**  
Pavement Characteristics Affecting the Noise Levels at Different Frequencies

Significant Variables										
500 Hz	630 Hz	800 Hz	1,000 Hz	1,250 Hz	1,600 Hz	2,000 Hz	2,500 Hz	3,150 Hz	4,000 Hz	5,000 Hz
MPD (+)	MPD (+)	Mix type (-)	Mix type (-)	AV (-)	AV (-)	AV (-)	AV (-)	AV (-)	AV (-)	AV (-)
RMS (+)	RMS (+)	FM (-)	AV (-)	Mix type (-)	Cu (+)	Mix type (-)	Mix type (-)	RMS (-)	RMS (-)	RMS (-)
AV (+)	AV (+)	Cu (+)	Cu (+)	Cu (+)	Mix type (-)	Cu (+)	RMS (-)	MPD (-)	MPD (-)	FM (-)
FM (+)	IRI (+)	Air-void Content (-)	FM (-)	Age(+)	FM (-)	FM (-)	Cu (+)	FM (-)	FM (-)	MPD (-)
Mix type (+)	Surface Thickness (-)	IRI (+)	Surface Thickness (+)	FM (-)	Surface Thickness (+)	RMS (-)	FM (-)	Cu (+)	Cu (+)	Cu (+)
Cu (-)	Cu (-)	Rubber Inclusion (-)	NMAS (+)	NMAS (+)	RMS (-)	Surface Thickness (+)	MPD (-)	Mix type (-)	Mix type (-)	Mix type (-)
IRI (+)	Mix type (+)		IRI (+)	Presence of Transverse Cracking (+)	NMAS (+)	MPD (-)	Surface Thickness (+)	Surface Thickness (+)	Surface Thickness (+)	Surface Thickness (+)
Surface Thickness (-)	FM (+)			IRI (+)	MPD (-)	NMAS (+)	Transverse Cracking (+)	Transverse Cracking (+)	Transverse Cracking (+)	Transverse Cracking (+)
				Fatigue Cracking (+)	Age(+)	Transverse Cracking (+)	NMAS (+)		Age(+)	
				Surface Thickness (+)	Transverse Cracking (+)	Fatigue Cracking (+)				
					Fatigue Cracking (+)					

Notes: Surface type and presence of fatigue and transverse cracking are categorical variables and are coded as "0" or "1" in the regression analysis.

## SUMMARY AND CONCLUSIONS

This study evaluated the effects of air void content, age, surface distresses, roughness, texture, and surface layer thickness on the overall sound intensity levels as well as frequency content of sound intensity levels. The pavements studied include open graded mixes, conventional and rubberized; gap graded rubberized mixes; and dense graded mixes that are less than 8 years old. The variation of sound intensity levels at different ages for different mixes was presented. The pavement characteristics affecting the overall noise levels were identified using correlation analysis while the pavement characteristics affecting the frequency content of sound intensity levels were investigated using regression analysis.

The results showed that open graded and gap graded mixes have lower noise levels than dense graded mixes. Gap graded mixes are the quietest mixes among all the mixes that are less than a year old while open graded mixes are the quietest among mixes older than one year.

It was found that increasing air void content and fineness modulus reduce the noise levels while increasing roughness (IRI) and the gradation's coefficient of uniformity increase the noise levels. The trend between pavement surface thickness and air void content for open graded mixes suggested that increasing thickness may reduce the noise levels for thicknesses above 50 mm. It was also shown that increasing air void reduces the noise levels of dense and gap graded mixes while open graded mixes are quite insensitive to air void content changes. As expected, the noise levels increase with age and with the presence of raveling and transverse cracking on the pavement surface.

Increasing air void content and texture reduce the noise levels at higher frequencies. It is known that human ear is more sensitive to high frequency noise, therefore open-graded mixes which have higher air void content and surface texture may be perceived as quieter even though the overall A-weighted noise levels are not significantly different than those of dense-graded mixes.

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# FUZZY MEDICAL WASTE DISPOSAL FACILITY LOCATION PROBLEM

Yeşim KOP<sup>1</sup>, Mijde EROL GENEVOIS<sup>2</sup> and H. Ziya ULUKAN<sup>3</sup>

**Abstract** — This paper provides a two step solution procedures for medical waste disposal facility location problem in Istanbul. Medical waste must be disposed without damaging environment and human health, complying with new regulations. Our aim is to provide an alternative method to the medical facility location problem in Istanbul, able to handle the fuzziness of the real world. People attempt to minimize the undesirable effects introduced by the new facility by maximizing its minimum Euclidean distance with respect to all demand points and also to minimize the total transportation costs. In our study, we propose the following two step solution procedure where we obtain all efficient solutions at the first step and then we choose the best solution at the second step. We use the Ishii's model to obtain a list of candidate points. Then, we made a selection between these candidate points by solving the fuzzy goal programming problem.

**Keywords** — Fuzzy facility location, Fuzzy goal programming, Maximin, Medical Waste

## INTRODUCTION

Recently, the controlled collection and safe disposal of medical waste has become an important field of environment protection in Turkey as in whole world. The 50% of environmental pollution has occurred in last 35 years. As a result, the scientists work on eliminating all harmful factors on air, earth, water and human life. The safe disposal and the regain of waste are some of the important fields that they work on. Even if the medical waste consist a small part of waste amount, considering the threat they constitute on human life, their safe disposal is vital.

The infectious, pathological, cutter-driller wastes emanating from medical institutions are known as medical wastes. Throwing away without control or common disposal with household waste poses a serious threat for all livings. That is why medical waste must be disposed without damaging the human mental and physical health, the animal health, the flora, the water and the welfare of the society, complying with new regulations.

The aim of this study is to provide an alternative method to solve the medical facility location problem in Istanbul, able to handle the fuzziness of transportation costs and people preferences. Nuclear plant, oil refining plant, waste disposal plant are plants undesirable close to residential area. People attempt to minimize the undesirable effects introduced by the new facility by maximizing its minimum Euclidean distance with respect to all demand points and also to minimize the total transportation costs. These are semi-obnoxious facilities and to locate them, facility planners determined two objectives [1]. The first aims to maximize the minimum distance from the new facility to the demand points; this is the maximin problem. The second aim is to minimize the total distance from the facility to the demand points in order to minimize the transportation costs. In our study, we propose the following two-step solution procedure where we obtain all efficient solutions at the first step and then we choose the best solution at the second step. Considering the fuzzy nature of the people attitude towards the location of this kind of facilities we will try to find the site of the facility which maximizes the minimal satisfaction degree among all demand points and maximizes the preference of the site by using a method based on the Ishii's where the attitudes of people are expressed by a trapezoidal membership function [2]. The function represents the satisfaction degree of demand points with respect to the distance from these points to the facility site. We reformulate the Ishii's model to obtain a list of candidate points. Then, we made a selection between these candidate points by solving the fuzzy obnoxious facility location problem, using an algorithm based on the Chen's [3].

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## DISPOSAL OF MEDICAL WASTE

There are many proven techniques for the safe disposal of medical waste all around the world. Nowadays, new contagious diseases that appeared in diverse countries induced all medical authorities to take severe precautions. In 2003, with the outbreak of severe acute respiratory syndrome (SARS) the authorities take more serious steps in managing medical waste. The procedures for handling, treatment and disposal of this waste were required to comply with the most stringent standards [4]-[5]. The health authority in Taiwan had to handle the current status of waste production for further management planning. The quantity of waste generated by hospitals varied by changes in local legislation according to the studies [6]-[7]-[8]-[9].

In Turkey, the medical waste production increases due to the economic and social changes and the population increase. The amount of waste is too huge to dispose in the dumping ground and requires an integrated management concept involving collection, transportation and disposal. By 2005 the number of hospital in Turkey has become 1198 and due to development of medical technologies and hygienic precautions total waste amount has been increasing. According to MEF's researches, total waste amount in Turkey is 238.26 tons per day and 86 968 tons per year. 23 000 tons of this amount is collected in Istanbul by ISTAC (sub institution of Istanbul Metropolitan Municipality) and district municipalities.

The mortal contagious diseases that appeared recently in Turkey as Avian Influenza, as well-known name bird flu, Crimean-congo haemorrhagic fever (CCHF) and the holocausts related to these diseases, furthermore the increase of other contagious diseases as aids, hepatitis and tuberculosis accentuate the vitality of the collection and the safe disposal of medical waste.

The regulations of medical waste control inure on 20.07.2005 in Turkey. The regulations are based on the 8<sup>th</sup> article of the environment code where it is denoted that inappropriate collection, transportation and disposal are forbidden. In the 35<sup>th</sup> article of regulations there is a legal decision on the medical waste disposal facility location: The distance of disposal facility can't be closer than 1000 meters to the residential area.

## METHODOLOGY

### Fuzzy Facility Location with Preference of Candidate Sites

Facilities as power plants, chemical plants, dumping grounds, airports are undesired close to residential area but they must also be at a reasonable distance easy to reach in order to minimize transportation costs. By using different decision making methods we must compromise two objectives. People don't want to live near a dumping ground but want also to get rid of the waste they produce as fast as possible. So we can not place the facility to an inaccessible distance.

The first step of this study is based on the Ishii's fuzzy facility location problem (2007), where the attitudes of the demand points (people, clients) towards the location of new facility are expressed by a trapezoidal membership function [2]. We reformulate Ishii's problem to obtain a list of candidate points. Ishii categorizes people attitudes in three categories. In our study we have two categories of attitude: 1. People don't want the facility near. 2. People don't want high costs of transportation. As it is mentioned in the medical waste regulations the burning and storage facility can not be close more than 1000 meters. Anyway people prefer the facility to be more than 5000 meters far from their residential area.

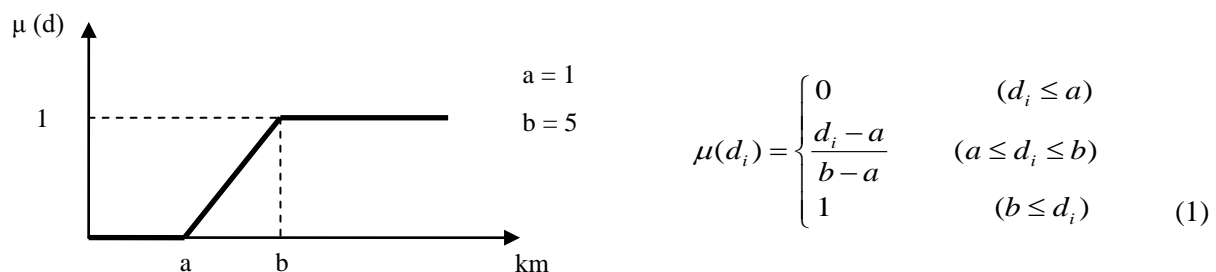


FIGURE. 1  
Membership function related to distances.

$$d_i(X) = \begin{cases} E(x - p_i) + N(y - q_i) & (x \geq p_i, y \geq q_i) \\ W(x - p_i) + N(y - q_i) & (x \leq p_i, y \geq q_i) \\ E(x - p_i) + S(y - q_i) & (x \geq p_i, y \leq q_i) \\ W(x - p_i) + S(y - q_i) & (x \leq p_i, y \leq q_i) \end{cases} \quad (2)$$

N: North = 1; S: South = -1; E: East = 1; W: West = -1

Let be  $n$  demand points in the rectangular area. These points are represented as  $(p_i, q_i)$ ,  $i = 1, 2, \dots, n$ . The facility that we will build is represented as  $X(x, y)$  and  $X = \{(x, y) | p_A \leq x \leq p_U, q_A \leq y \leq q_U\}$  [2].

Define  $\alpha : \alpha = \mu(d_i)$ . Then, we model our problem as [2]:

$$\begin{aligned} &P: \text{Maximize } \alpha \\ &\text{s.t.} \\ &\quad \alpha \leq \frac{d_i(x) - a}{b - a} \\ &\quad 0 < \alpha \leq 1 \\ &\quad p_L \leq x \leq p_U \\ &\quad q_L \leq y \leq q_U \end{aligned} \quad (3)$$

But the way that we will pursue to solve this problem is to partition the rectangular area to small rectangles by tracing the horizontal and vertical lines passing by each demand points. For each line intersection point called  $x_{jm}$  we will solve the sub problem below. The optimums of each sub problem can be handled by another decision making tool in order to select the best location for our facility.

$$\begin{aligned} &Q^\beta: \text{Maximize } \alpha \\ &\text{s.t.} \\ &\quad \alpha(b - a) + a \leq E(x - p_i) + N(y - q_i) \\ &\quad \alpha(b - a) + a \leq W(x - p_i) + N(y - q_i) \\ &\quad \alpha(b - a) + a \leq E(x - p_i) + S(y - q_i) \\ &\quad \alpha(b - a) + a \leq W(x - p_i) + S(y - q_i) \\ &\quad 0 < \alpha \leq 1 \quad x \in X^\beta \quad i = 1, 2, \dots, n \end{aligned} \quad (4)$$

### Selection of the Best Candidate Site with Fuzzy Goal Programming

A starting point for the GP model can be found by restating the LP model, its assumptions and modeling notation. Each constraint that makes up an LP model is separate function, called a functional. These functionals are viewed as individual objectives or goals to be attained.

Charnes and Cooper (1961) referring to these functionals as goals, suggested that goal attainment is achieved by minimizing their absolute deviation. They illustrated how that deviation could be minimized by placing the variables representing deviation directly in the objective function of the model. This allows multiple goals to be expressed in a model that will permit a solution to be found. A generally accepted statement of this type of GP model was presented in Charnes and Cooper (1977), [10].

To deal with uncertainty, many attempts have been made but the most fruitful was the theory of Zadeh. Since the single objective fuzzy linear programming (FLP) study made by Zimmermann in 1976 and multi objective fuzzy linear programming in 1978, the fuzzy theory has been applied to many decision making problems. One of these applications is the fuzzy goal programming (FGP) study of Narsimhan in 1980 with imprecise aspiration levels of fuzzy goals. There are many studies involving different kinds of FGP method to deal with uncertain data about a certain parameter (fuzzy alternatives, fuzzy objective functions, fuzzy deviation functions etc.). The study of Hannan in 1981 represents a fuzzy logic based method where decision maker satisfaction in goal attaining are represented by piecewise linear functions [12]. In 1991, nonlinear membership functions are used in FGP by Yang, Ignizio and Kim. Tiwari et al. (1987) proposed a method

similar to lexicographic GP where the problem is decomposed into  $n$  sub problems. Here,  $n$  is the number of preemptive priority levels [13].

To solve our FGP model we use the algorithm proposed by Huey-Kuo Chen, 1994, which is a modified version of the method developed by Tiwari, Dharmar and Rao in 1993, [3].

Our solving algorithm uses symmetrically triangular membership functions of fuzzy goals. The membership function of this FGP is [3]:

$$\mu_i(AX) = \begin{cases} 1 & \text{if } (AX)_i = g_i \\ 0 & \text{if } (AX)_i \leq \underline{g}_i \\ \frac{(AX)_i - \underline{g}_i}{\Delta_i} & \text{if } \underline{g}_i \leq (AX)_i \leq g_i \\ \frac{\overline{g}_i - (AX)_i}{\Delta_i} & \text{if } g_i \leq (AX)_i \leq \overline{g}_i \\ 0 & \text{if } \overline{g}_i \leq (AX)_i \end{cases} \quad (5)$$

The aim of the method proposed by Tiwari et al. is to find the maximum membership value by enumerating all possible combinations which cover the entire feasible region. We consider two subsets which are left and right hand sides intersecting at the point having the highest membership value equal to 1.

Therefore, there will be  $2^m$  sub problems taking into account of different combinations of membership functions of fuzzy goals [3]:

$$\max_{x \geq 0} \lambda = \left[ \min_i \left\{ \frac{(AX)_i - \underline{g}_i}{\Delta_i} \right\} \right] \quad \text{and} \quad \max_{x \geq 0} \lambda = \left[ \min_i \left\{ \frac{\overline{g}_i - (AX)_i}{\Delta_i} \right\} \right]$$

$$\underline{g}_i \leq (AX)_i \leq g_i \quad i = 1, 2, \dots, m \quad g_i \leq (AX)_i \leq \overline{g}_i \quad i = 1, 2, \dots, m \quad (6)-(7)$$

As the sub problems are linear with a single objective function, the FGP method has the advantage that a commercially available software as LINDO may be used for solving it.

## APPLICATION

This two-step model is applied to the medical waste facility selection for the most populated region of Istanbul including the districts Şişli, Kağıthane, Beşiktaş, Sarıyer. The figure below is the Google Earth map showing the application region. The distances and coordinates are provided by Google Earth (Figure 2).



FIGURE. 2  
Selection of a medical waste disposal facility in Istanbul.

In rectangular area there are four demand points and all lines passing through form 25 points which means that we will solve the sub problem (4) 25 times. The optimum membership values and optimum candidate facility sites are given in the table below. As our aim is to maximize membership value  $\alpha$ , we can select the biggest  $\alpha$  value as new facility site but there are many  $\alpha$  values closer to each other. So, the most reasonable attitude is to handle some candidate points having big  $\alpha$  value, considering other factors like cost and waste

amount of each demand point. In our study, we will handle seven points having  $\alpha$  value bigger than 0.600 in terms of an observation made on the map and we will make our selection by solving a fuzzy goal programming problem for facility location.

TABLE 1  
Optimum  $\alpha$  values and optimum candidate facility sites

SUB PROBLEMS	OPTIMUM POINT	OPTIMUM $\alpha$ VALUE	SUB PROBLEM	OPTIMUM POINT	OPTIMUM $\alpha$ VALUE
1	-	-	14	(6.350; 7.110)	0.422
2	(1.790; 3.450)	0.110	15	(2.675; 0.000)	0.549
3	(6.350; 0.000)	0.140	16	(0.000; 0.565)	0.565
4	(5.330; 7.110)	0.167	17	(3.230; 7.110)	0.567
5	(5.080; 2.160)	0.217	18	(6.350; 3.645)	0.579
6	(5.080; 3.645)	0.261	19	(1.640; 5.645)	0.621
7	(5.330; 3.645)	0.324	20	(6.350; 3.045)	0.631
8	(4.445; 2.160)	0.376	21	(0.000; 3.100)	0.645
9	(5.080; 2.795)	0.376	22	(0.000; 0.000)	0.700
10	(5.080; 2.795)	0.376	23	(1.640; 7.110)	0.965
11	(3.230; 0.000)	0.410	24	(0.000; 5.520)	1.000
12	(6.350; 2.160)	0.410	25	(0.080; 5.690)	1.000
13	(2.675; 0.540)	0.413			

Our first goal is to maximize the  $\alpha$  value and the second goal is to minimize the total transportations cost from the new facility to the demand points (minisum). As we have 2 goals, we have to solve  $2^2$  subproblems. Our seven candidate waste disposal facilities are highlight in the Table 1 and the medical waste amounts of each districts (demand points) are in the Table 2. These amounts will help us to determine the weights of each district that we will use in the minisum goal. Table 3 contains the distance between all demand points and candidate sites.

TABLE 2  
Waste amounts of each district and weights (Istanbul Metropolitan Municipality)

DISTRICTS	MEDICAL WASTE	
	AMOUNT (KG/YEAR)	WEIGHT
SISLI	87 600	0.362
BESİKTAS	64 800	0.268
KAGITHANE	64 800	0.268
SARIYER	24 600	0.102

TABLE 3  
Distances of candidate sites to each demand point

CANDIDATE SITE	SISLI	BESİKTAS	KAGITHANE	SARIYER
1	6.680	5.870	3.800	10.770
2	3.580	7.890	2.580	7.670
3	3.525	3.525	5.595	3.915
4	5.300	10.310	5.000	5.250
5	3.785	8.795	3.485	3.485
6	5.390	10.400	5.090	5.000
7	5.250	10.260	4.950	4.860

Our objectives are:

$$G_1 : \max \sum_{j=1}^7 \alpha_j z_j \quad \text{where } z_j \in \{0,1\}$$

$$G_2 : \min \sum_{j=1}^7 \left[ \left( \sum_{i=1}^4 w_i d_{ij} \right) z_j \right] \quad \text{where } \begin{cases} z_j \in \{0,1\} \\ d_{ij} \text{ are distances} \\ w_i \text{ are weights} \end{cases} \quad (8)$$

We solve our fuzzy goal programming problem using Chen's algorithm. We use LINDO as tool and we found that we can construct our medical waste disposal facility to the candidate site 6: (0.080; 5.690). This point is in a green area at Şişli. This area is sufficiently far from residential area and not too far to increase the

transportation costs. So we can conclude that our study is meaningful for this kind of problems. But there can be also other logistical constraints. In that case this model may be weak.

## CONCLUSION

This paper deals with the problem of determining the undesirable facility location site in Istanbul. This kind of problems own naturally two objectives one is to maximize the minimum distance from the new facility to the demand points and the second is to minimize the total distance from the facility to the demand points in order to minimize the transportation costs. We tried first to find the site of the facility which maximizes the minimal satisfaction degree among all demand points and maximizes the preference of the site by using a method based on the Ishii's. We used fuzzy membership function to represent the attitudes of demand points related to the distances between demand points and new facility location. By maximizing the membership value we try to find the optimum point. There are two drawbacks of this kind of solution procedure. The first is that this model suggests that residential areas are points discrete. This problem can be handled by revising the intervals of membership function. Second is that more than one sub-problem can have the same optimum solution. To handle this problem we use the optimum points having nearly same values bigger than a fixed value to solve a fuzzy goal programming where we add the minisum objective. After that procedure we obtain a unique solution optimizing the two objectives. The apparent advantage of our solution procedure is that all problems are converted to linear problems and we solve them easily using LINDO software.

## ACKNOWLEDGMENT

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# **Chapter 13**

Transport Infrastructure and Investment Appraisal





# AGENTS' BEHAVIOUR IN FINANCING ITALIAN TRANSPORT INFRASTRUCTURES

Paolo BERIA<sup>1</sup>

**Abstract** — *The aim of the paper is to critically describe the behaviour of the main Italian transport infrastructural agents (national roads and rails, highway, airports concessions) in the field of infrastructure financing. All the actors are trying to avoid the effects of regulation and, at the same time, to reinforce their dominant position and power. The thesis of the paper is that the funding and building of new infrastructures is often the pillar of this strategy, since this is the field where the legal framework is weaker.*

*A short review of the present normative is followed by the description of the behaviour of the main agents. Recent planning documents will be commented, pointing out the tendency of the regulated monopolists to find out new strategies to maximise their objectives. Among these, the proposal of new infrastructures is the field where monopolists are more active and where regulation should be more effective.*

**Keywords** — *regulation, investment, infrastructure, airports, roads, highways, railroads, price cap.*

## INTRODUCTION: INVESTMENTS AND REGULATION

The aim of the paper is to critically describe the behaviour of the main Italian transport infrastructural agents in the field of infrastructure financing. All the actors are trying, according to the structure of respective markets, to avoid or minimise the effects of regulation and, at the same time, to reinforce their position and power against the regulator. The thesis of the paper is that the funding and building of new infrastructures is often one of the pillars of this strategy, since this is the field where the regulatory framework is weaker.

The topic of the relationship between the regulation of transport markets and the investments in new infrastructures is seldom discussed. The well-known approaches of privatisation, *price-cap*, yardstick competition, tenders, etc. do not explicitly consider the investments as part of the regulatory problem or do it in a way that reveals as non satisfactory in the practice. In particular, the *price-cap*, one of the most applied methods for the regulation of non contestable sectors and of natural monopolies, does not distinguish in the majority of applications, the type of investment.

As discussed before in Beria and Ponti (2008), in fact, a distinction between “endogenous” and “exogenous” investments is necessary to avoid the tendency to overinvestment or gold-plating practices. The “endogenous” investments are those that reduce the costs (introducing a new technology, for example) or raise the demand (building a new section) at a level that makes the investment self-profitable for the regulated actor, also at a given tariff. In other words, for these investments an explicit remuneration is not necessary because self-financing. To the contrary, those investments that are not able to raise revenues or lower costs at a level that make them profitable, should be exogenously financed through a tariff increase or public lump sum subsidies. This, of course, only in case they result profitable in socio-economic terms.

The lack of distinction between those two categories and the remuneration through tariff increases of any kind of investment, may generate extra-profits. This gives an incentive to overinvestment, at the expenses of the users that pay unnecessarily high tariffs. The already mentioned paper demonstrated the wide occurrence of this practice in Italian regulated sectors.

The present paper aims to investigate a further aspect of the problem of investments done by a regulated (or a weakly-regulated) concessionaire or agency. This aspect deals with the use of investments to increase the contracting power of the regulated, up to the substitution of the public planner with a private-like (or even private) planner, and to grant long term monopoly and rents. In some cases this behaviour lays in the insufficiency of the regulatory normative; in other cases it is the outcome of an opaque application of it or of the capture of the regulator by the agent. In this second case it is not always possible to bring proofs supporting facts that are actually circumstantiated impressions.

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The paper starts with a short review of the present Italian normative, followed by the description of the behaviour of the main agents and modes, namely the highway concessionaires, the national road agency, the national railways and the major airport concessionaires. Some conclusions will be drawn at the end.

### BRIEF NORMATIVE OVERVIEW

The Italian normative framework is supposed to regulate all the transport natural monopolies through fares, both in terms of operations and financing. However, the normative is not homogeneous among the modes and largely insufficient to promote efficiency (Ponti et al., 2007).

Highway and airport fares are regulated via *price-cap*. In both cases the regulation applied is unsatisfactory due to the lack of actual pressure to efficiency and for the favourable investment remuneration (Beria and Ponti, 2008, Ragazzi, 2008).

Rail track access tolls are calculated with a formula defined in a decree. There is no *price-cap* or any other form of efficiency promoting mechanism. Rail services fares are defined by the state or by the regions (for those considered as social services) or are *de facto* left to the incumbent operator choice.

Road system is free of charge and no regulation on subsidies is present.

Since the national regulatory framework is so contradictory, it is generally not completely effective. Major rents are still present, also in form of inefficiency. Concerning the financing, some effects can be recognised in the past, like “gold plating” and cost overruns.

### GOLD PLATING AND PROFITS IN THE HIGHWAY SECTOR

Italian highway system consists of approximately 6.500 km, the majority of which is franchised. Part of this network, 600 km, has characteristics of highway, but is built and owned by the National Road agency ANAS (see below). The concessionaires are 25, usually privately owned or mixed public-private. The main concessionaire is the private company group “*Autostrade*”, which owns the 61% of the network and serves the 67% of the traffic. It was formerly owned by the state and was privatised in 1999. Another group, the “Gruppo Gavio” owns the 20% of the network. The rest of the network is owned by local authorities or by minor private shareholders (Ragazzi, 2008).

#### The privatisations and the extension of concessions

Until the end of the Nineties, all the concessions were automatically renewed at the same conditions and without any tender. The renewal was formally justified with the promise of further investments, which needed to be adequately remunerated. In 1999, the Government decided to privatise the main concession, “*Autostrade*” in order to accomplish at European request to dismantle the former owner, IRI, a public company. However, the hidden rationale of such privatisation was to earn as much as possible in a period of financial constraints by expanding the value of the stocks (Boitani, 2004; Coco and Ponti, 2006).

The maximisation of the company value was done by introducing some distortions in the *price-cap* mechanism adopted since 1996 for the yearly update of the tolls. These distortions regard both the lack of an effective incentive to efficiency maximisation and profit minimisation, and the issue of investments.

According to the decree named “Costa-Ciampi” (20 October 1998, n. 283), following the criterion of past costs recovery, the renewal periods *should* have been very limited for all the concessions (1 to 7 years, with only one exception of 18 years) (Ragazzi, 2008). This short concession was a threat for the survival of the present concessionaires. In few years all of them should have transferred the infrastructure back to the regulator, due to the fact that all their investments were completely repaid and widely remunerated.

However, the still public “*Autostrade*” obtained easily the renewal of the concession for another 40 years up to 2038, just before the privatisation and without any tender (in 1997, until 2038). This fact opened the way, between 1999 and 2000, for many other concessionaires to conveniently extend their concession period, despite the European rules forbidding automatic renewals without tendering.

The mix of weak regulation, extension of the concession and approval of huge investment plans, made ex-post *Autostrade* (but also the other concessions) extremely profitable for the investor and increased noteworthy its value<sup>2</sup>. The counterpart is that such a favourable regulation cannot, by definition, promote efficiency and favour the users.

<sup>2</sup> Boitani (2004) quotes some documents of that time evidencing the fact that the expected profits of *Autostrade* were largely superior to the official ones, due to the particularly favourable regulatory framework.

### Price-cap and new investments

The main justification to the extension of the concessions to Autostrade and to the other networks under expiration, laid in the field of new investments.

In fact, all the concessionaires succeeded in having a further concession period in order to repay *new* investment plans. These investments, once their social utility was demonstrated, could have been properly financed by fixing an end of concession value to be paid by the new concessionaire after the expiration of the present one. This would have avoided of having longer concession periods before tenders. However, this did not happen and concessions were extended for 6 to 27 years (with two shorter exceptions only). Moreover, only few concessions would have expired around 2010<sup>3</sup>, all the rest around 2020 or later, up to 2038<sup>4</sup>. The extension was calculated as the sum of the extension due to the past unrecovered investments, plus the extension due to recover the future, declared, investments. The new investments, with the exclusion of *Autostrade*, consisted in approx. 4.500M€. The figure is slightly lower than the initial proposal made by the concessionaires of approx. 5.500M€ (Ragazzi, 2008).

As already mentioned, the remuneration is done by applying, since 2000, a new regulatory regime ruled by a *price cap* formula. However, the model applied is very far from the theoretical one (Coco and Ponti, 2006) especially concerning investments. The principle determining fares is that of uniformity across parts of the network and tariffs are, in fact, defined to fully recover the investment costs. No criterion is applied in order to efficiently allocate the demand (Boitani, 2004). The effect seems to be that these investments are not only *not risky*, due to the favourable *price-cap*, but also that they are assessed by the concessionaire and not by the regulator, whose control on methodology and unit costs is not transparent. Moreover, as Italian norms require, the assessment refers to single, specific, investments and not to a plan. Finally, there is no distinction between endogenous investments, i.e. those that can be directly financed through the direct increase of demand or lower of operating costs, and exogenous investments, i.e. those that must be paid by public funds or by other users because not self-profitable (Beria and Ponti, 2008).

The outcome of this normative framework (together with the feeble assessment process used in Italy, especially at the planning level) is to stimulate overinvestment: the more investments (promised), the longest is the concession period and the higher can be the tolls.

The important modifications introduced with CIPE decree 1/2007 were not sufficient to limit the power of the concessionaires, but only to stop for one year (2007) the increase of tolls<sup>5</sup> (Ragazzi, 2008). The decree has been issued because of many cases of investments declared, included and paid in tolls, but actually never built. The resistance of all the concessionaires to this decree has been strong.

Another correction of the past, problematic, framework deals with the quantification of the value of the investment. Before 2007, the amount of the investment was updated at the end on the basis of the declared ex-post costs. This did not give any incentive to correctly forecast the investment cost and opened the way to large and incontrollable overruns. Since 2007 the investment remunerated in *price cap* formula is the one declared ex-ante by the promoter – concessionaire.

Recently (2008), the formula is, once again, under modification, this time in favour of concessionaires. In the future, the price-cap formula will fix also the “X” parameter to a predetermined share of the inflation rate, neutralising also any driver to efficiency.

### Regulation or incentive to gold-plating?

The given description stresses that the Italian regulatory framework concerning highways investments is critical. It is not only a matter of weakness and normative inadequacy. Rather, some contents of the regulation are distorting the sector and inducing opportunistic behaviours of the agents. Their resistance has been until now capable of reducing the effectiveness of the regulation.

Some problems, limiting the analysis to the field of the investment choices only, can be stressed.

- a. The way initial tariffs are set, i.e. the “historical” ones, determines an unregulated monopolistic rent once the past investments are repaid.

<sup>3</sup> Centropadane (Piacenza-Brescia) in 2011, Cisa (Parma-La Spezia) in 2010, Padova- Mestre in 2009.

<sup>4</sup> Torino – Savona.

<sup>5</sup> For example, *Autostrade per l'Italia* had an increase of only 0,17% instead of 2,93% if calculated with the previous rules. This means that the phenomenon of declared but not realised investments is crucial.

- b. New investments are automatically remunerated in the tariff, without applying any efficiency criterion and in a scarcely transparent way. Moreover, these increases are spread on the whole network even if benefits (e.g. a new section) are limited to some users only (Boitani, 2004).
- c. The extension of the concession and the extra-remuneration of new investments during the concession period mean that new investments are paid *twice* (Ragazzi, 2008).
- d. Present contracts remunerate any kind of investment. However, only exogenous ones should be remunerated (Beria and Ponti, 2008).
- e. Every new investment is proposed by the concessionaire (Ponti and Boitani, 2005), which actually acts as a planner. The plan is only formally approved by ANAS, which is supposed to be the planner/regulator. The distinction between investments promoted by the concessionaire (to be paid by new demand or cost reduction) and by the authority/planner (to be paid in tariff or by a tender) is necessary, but absent.

The outcomes of this regulatory framework are important. Privatisation and regulation aimed at maximising the value of the public companies to be privatised and not to obtain efficiency and fair tolls. The consequence is that now the concessionaires are doing, with no exceptions, extraordinary extra-profits (Ragazzi, 2008), increasing their already strong position in front of the state. Also the transparency of such profits is scarce. Furthermore, no productive and allocative efficiency is promoted.

A perverse incentive to overinvestment is given, known as *Averch-Johnson effect*, both in quantity (new and unnecessary investments) and in unitary prices (no control on cost overruns and inefficient engineering situations, defined as *gold plating*) (Gomez Ibanez, 2003). Obtaining the approval of monumental and unjustified investment plans, even if longer than the concession period, is easy. This behaviour, even if not linked to a longer concession period, gives *immediately* extra-profits (Ponti and Boitani, 2005), thanks to the price-cap parameter. Moreover, the socio-economic rationale of these investments is weakly verified by the authority. ANAS, in fact, approved investments plans without any priority verification, stressing that investments are not publicly funded.

## NATIONAL ROADS: A STATE AGENT BECOMING A POWERFUL PLANNER

The Italian national road system consists of approx. 21.500 km, including some 4 lanes roads and approx. 1.200 km of highways or roads with characteristics of highways. All its network, except part of the highways, is completely free. The whole national system is managed by one single concessionaire, named ANAS<sup>6</sup> and 100% owned by the Treasury. The concession will expire in 2030<sup>7</sup>.

ANAS is now a stock company, even if fully state owned, but its financial autonomy is still very scarce and depends mainly on earmarked state transfers. In the past the “strategy” of the agency was quite simple and typical of the operative branches of ministries. Its task was to build, maintain and operate the national network, under state transfer and monopoly conditions.

However, due to historical reasons, ANAS is not only the network manager. It is also in charge of an authority-like function for franchised highways. Under this function, it manages the bids and regulates the fares of the concessions. However, ANAS is now in charge also of some expired toll concessions and aims to introduce tolls on many trunk roads: this double function is generating a conflict of interests and threatening its independence as authority.

### The industrial plan 2007-2052 and a new powerful actor

The analysis of ANAS case became recently extremely significant, after the recent issue of an ambitious industrial plan. The plan, transmitted to the Treasury in June 2007, is still under approval in 2008<sup>8</sup>.

The agent is dependent, both on operation and investments, on the actual state transfers, allocated by law every year. Since transfers come always from the state or from local budget, ANAS concur to national debt, constrained by European agreements. The largest part of national transfers is, up to now, for new investments, that sum up to more than 1 billion Euros per year, with few exceptions<sup>9</sup>.

<sup>6</sup> Also Provinces and Municipalities build and manage their own road networks.

<sup>7</sup> Unless renewed until 2050 as requested by the agency itself.

<sup>8</sup> The first comments of the technicians of the Ministry is extremely “cautious” (Ministero Economia, 2008).

<sup>9</sup> The year 2006 was an anomaly, with “only” 100M€ spent.

ANAS dependency on end-of-budget state transfers and the stochastic character of them across years, limits the actual responsibility of the managers towards an efficient behaviour. It is not surprising that the budget showed very negative results often in the past years, despite the large transfers.

In 2007 a new industrial plan has been issued, covering a very long period until 2052. It is proposing radical modifications on the status, the role and the autonomy of ANAS. The plan has not been approved yet at the moment of writing, but it will likely be.

The key issues of the plan are listed below. All of them are heavily affecting the way Italian roads will be financed in the future (Beria and Ponti, 2008):

- introduction of shadow tolls and real tolls on some trunk roads, now free. State subsidies remain for the “non commercial” network;
- acquisition of the network of some highway concessions under expiration;
- some new roads will be financed by ANAS budget (obviously larger than now) instead of direct state transfers. Direct funding remains for the new “non commercial” roads, i.e. the large majority.

All these measures have the primary purpose to “deconsolidate” ANAS from the Italian public debt. Also, the public ownership, the sovereign guarantee, the status of legal monopoly and the lack of any regulation makes ANAS financial rating high and very attractive for borrowing loans and for private investors.

The plan demonstrates the huge importance of investments in defining the strategy of the actor. ANAS is mainly aiming at becoming an independent subject, independently promoting development plans, increasing revenues, introducing tolls and increasing debt expositions. However, the ambiguous status of public company and of authority, in contradiction with the new role of market agent, was never put into discussion.

Many comments can be drawn on the most questionable aspects of the proposed evolution, especially related to the investment topic:

- Huge increase of the dimension of ANAS in terms of assets, including the whole trunk road network, all the highway concession under expiration and the whole new network that they will decide to build. Also the functions are increasing in number and extent: not only regulator and agent, but also concessionaire of many main roads.
- There is no clear discussion on the most efficient dimension of the road monopolist, which is now matching with national borders. Moreover, it is not demonstrated that further enlarging the dimension of the concession with new roads and functions goes in the right direction.
- No toll regulation is explicitly proposed. ANAS seems to become both the regulated actor and the regulator of itself.

The main argument used to support the evolution is related to investments, in particular the fact that the new rules allows to skip every state budget constraint and that new investments will come “at no cost”. The argument is fictitious. The source of funds for the financing of the new network is supposed to come mainly from the toll revenues. However, part of these revenues will continue to come from the state budget (with another name) and part from users that now have free roads. The projections included in the plan go from 15 millions of real tolls out of 185 millions of total toll revenues in 2012, to approx 1000 millions out of 2800 millions in 2052 (plus the transfers for the investments in the non commercial network). So, the largest part of revenues is still from treasury budget, differently from what stated.

But this is not the main point. Three further aspects must be underlined, stressing the importance of new investments regulation in ANAS strategy:

- The plan is based on the existence and perpetuation of the unregulated monopoly, which can dispose of the *totality* of the national network. Cross subsidisation is the rule, with profitable roads financing the ancillary network. Moreover, the monopoly is not regulated and the ambiguity of ANAS as regulator and concessionaire at the same time is not solved at all.
- The investment plan is the pretext for the increase of the dimension of the “agency”. The national dimension is never discussed. The agent prefers to be the largest possible to avoid competition (also in comparative terms) and to maximise the contracting power.
- The selection of new investments (in other words, the planning of national network) will move from ministry and public agency to a private-like company, whose goal is profit. The list of projects is no more supposed to come from central planning, at least for the main network. The risk of capture and *gold plating* is present, both rising unitary costs due to lack of regulation, and allocating resources out of an efficiency-based framework (Beria and Ponti, 2008).

## NEW RAILWAYS AND OVERCAPACITY

The Italian rail network consists of approx. 16.000 km in charge of the national railways (*Ferrovie dello Stato S.p.A.*), plus some 3.500km of conceded local railways. The main operator, *FS*, was formerly a vertically integrated public company in charge of the network and with the legal monopoly on services. After the introduction of liberalisation principles, the group has been divided into a service company (*Trenitalia*) and a network manager (*RFI*), plus some smaller specific societies<sup>10</sup>. However, all the companies are still grouped under one single public holding, *Ferrovie dello Stato S.p.A.*.

The financial soundness of *FS S.p.A.* is scarce. The budget of the company, also including state subsidies, is often performing null or negative operative results (Beria and Ponti, 2008). The liberalisation process in Italy is aligned with Europe, with some specificities. National railways have been unbundled, but tracks and services are still under the same state owned holding. Tracks are a legal monopoly managed by one single company and its tolls are defined via a decree. No *subsidy-cap* mechanisms exist. No discussion on the minimal efficient dimension of the network took place and the concession is one for the whole country. On goods sector, there is a penetration of new-entrants for approx. 10% in terms of tonn·km. For passengers, *Trenitalia* is still the monopolist both for long distance and regional services, even if both markets are legally opened (some new rail companies are nearly ready to enter in the market of high speed and some regions performed bids, always won by *Trenitalia* or by consortia including it). *FS* group is absent in logistics.

### Rail investments with no remuneration

Historically and presently, all new investments, especially those involving infrastructures, are fully state financed. In general, investment costs are transferred from public purse to *RFI*, that spends it. These subsidies are ruled by a contract, called “*Contratto di Programma*”, that includes the list of new projects that *RFI* will build and the cost for it.

The new infrastructures (or new equipments), excluding high speed lines, are never supposed to remunerate the investment, but only the running costs including maintenance. The amortization is *not* due for the new infrastructures financed by state transfers, except for part of the high speed network.

The Italian high speed network is under construction since the 90s<sup>11</sup> and will consist until 2010 in the line Turin – Milan – Rome – Salerno, plus some doublings between Milan and Venice. According to public declarations, the main line was initially supposed to cover the 60% of total investments with revenues from fares. Ten years later the line, not yet completed, is costing much more than expected and only 5,1 billions€ out of 24 are financed by equity, all the rest by public transfers (Ponti and Beria, 2007).

The average available capacity is described in the plan as “wide”. It is likely that no capacity constraints will exist after the construction of the main HS network Turin-Salerno. Only some terminals or urban sections suffer of congestion and must limit the introduction of new trains. Much more problematic in limiting the services is the lack of availability of appropriate rolling stock.

The ratio underlining the investments is contradictory.

The HS network under construction is positively seen by *FS*, because it is the only one capable to host profitable services. The investment cost has been paid for a very small share by the group, but the revenues constitute the largest part of total traffic revenues. Moreover, the HS service is seen as the only one attractive for the users and is thus necessary to improve the image of the company.

To the contrary, the largest part of the conventional network (and probably the majority of the HS extensions) is requested by the political bodies, with the exclusion of some urban doublings that are necessary to solve bottlenecks. *FS* and *Trenitalia* will not benefit of the extra capacity provided by doublings and new secondary lines, because the present capacity is still largely sufficient.

Moreover, the investments had, historically, also the function of hiding the lack of liquid resources. The transfers to *FS* for the investments constituted until 2000 a source of available money. However, the present definition of such transfers does not allow the “surround” anymore.

Finally, it is worth noting that the large capacity now existing on the main commercial network can also be a threat for the public company. The Italian long distance market is substantially opened and potentially very

<sup>10</sup> In charge, for example, of commercial revitalisation of major stations (“Grandistazioni”) or of estates development (“*FS Real Estate*”).

<sup>11</sup> With the exclusion of the Florence – Rome direct line dating back to the 80s.

attractive, despite the cross-subsidies benefiting FS. Some newcomers are entering in the market and picking the most profitable services only, thanks to the fact that the available capacity is large.

### AN AIRPORT IN EVERY CITY

The majority of Italian airports are managed by concessionaires, with the exception of some minor airports managed directly by the Civil Aviation authority. Often airports are franchised by public companies owned by local authorities. Only few private airports exist, especially among the larger ones. In particular, Rome and Naples airport systems have been privatised and the discussion about the Milan one is frequently at stake, even if not yet decided. Concessions are 40 years long.

Regulatory mechanisms have been modified in 2007 (Beria and Ponti, 2008). Both in 2000 and 2007 regulatory frameworks, a point of weakness raises in the issue of investments remuneration. Exactly as for any other regulated sector, investments that improve efficiency and give temporary extra profits to the concessionaires must not be remunerated. The concessionaire will decide independently whether it is worth doing that investment or not, and pay for it. Only when an investment gives a net social surplus, but not a benefit for the concessionaire, it must be publicly financed or paid by users through an increase of tariff.

A problem arises when *any* investment financially feasible at a given increase of tariff is proposed and then approved. This seems to be the situation of Italian airports regulation, where ENAC, that is called to approve investments and consequent tariff increase, do not perform any kind of *public* evaluation. The procedure usually followed should be the approval of a contract (“*contratto di programma*”) that may include various new investments, without an explicit estimation of their effect on demand, efficiency and profits<sup>12</sup>. In these cases there is no distinction between financially feasible investments (decreasing costs or rising demand) to be paid by airports and socially desirable ones: *all* investments are paid by an automatic increase of tariffs or by public transfers.

This fact is giving to the concessionaires a strong incentive to overinvestment. The outcome is that all Italian airports suffer of *overcapacity*, except Linate and Fiumicino (Sebastiani, 2004). Then, every expansion or investment is not unlocking new demand, before constrained, because no unsatisfied demand exists.

A second incentive to develop extra-capacity comes also from the local authorities, that tend to build and operate as much airports as possible<sup>13</sup>. This is due both to consensus practices (the airport is seen as a necessary tool for regional development), but also because of the expectations of large rents in a period of expanding air market.

### CONCLUSIONS

The present regulatory framework in Italy gives to the agencies many tools to enforce their positions, to increase profits or to minimise efforts. Aside to the “usual” tools described by literature (informative rents in contracts, capture power, dominant positions in the market, cross subsidies, etc.), this paper adds the issue of infrastructural investments.

We stress that the incumbent agencies are intensively using the tool of investments and the related informative rents on actual costs, to avoid the effects of regulation, because investments field is weakly regulated. The strategy of the agents is to take control also of the planning procedures and maximise the investments, in order to soften or avoid the regulatory pressure. For the regulated sectors, such as airports or highways, the investments are used to maximise profits thanks to a wrong toll regulation, usually focusing on services and fares. For the less regulated sectors, such as railways, the maximisation of investments has the traditional meaning of increasing the contracting power by expanding the assets.

ANAS, being a “newcomer” among the concessionaires, is a fundamental example of the aggressive strategic behaviours in this issue. Their strategy is heavily focusing on the relationship between infrastructural investments and market regulation, exploiting the weaknesses of the normative framework and the absence of an independent transport regulator. The evolution ANAS proposes for itself is to move from being a purely operative agent, becoming a planner and private-like investor. The argument of skipping national debt constraints is used to make attractive the industrial plan to the political decision maker, capturing it. The

<sup>12</sup> However, for reasons that cannot be discussed here, no contracts have been signed recently.

<sup>13</sup> Italy there are more than 100 airports, some of them really small, and nearly all of them are performing investments and expanding capacity.

counterpart of this, is the unlimited expansion of the dimension and power of the former agent that becomes a huge monopolist concessionaire.

The Italian highways explicitly benefited of an ineffective and favourable regulation, in order to maximise their financial value. The favourable conditions are based on the issue of the investments, that extend the concession on the basis of development plans proposed by the concessionaire and never assessed in terms of costs and utility by the regulator. The fact that the “regulator” (ANAS) is also a “potential” concessionaire is clearly introducing a conflict of interests: why ANAS should apply a stringent regulation and limit investments, if it plans to apply tolls and maximise their own investments? The statement included in the plan that the two roles will not conflict is not realistic at all.

Similar is the case of airport concessions, where the regulator ENAC is not limiting the investments, since they are wanted and paid by local authorities or paid by higher tariffs. The capture of it may be supposed. The airport companies, on their side, do not have any incentive to minimise investments, since the more facilities they build, the higher are the tariffs and the profits.

Railway sector is not lucrative and not regulated. For these reasons the use of investment is still limited to the expansion of the assets and to the tentative of surviving the competition with air and private car.

The general policy indication, discussed somewhere else (Beria and Ponti, 2008) is to subtract the topic of investments remuneration to the concessionaires, with the exclusion of the endogenous ones.

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# FREE TRADE AGREEMENTS IN THE MEDITERRANEAN REGION: A BOX-COX ANALYSIS

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**Abstract** — Free Trade Agreements (FTA) have been tools widely implemented for enhancing trade between countries. As a result, various models have been developed in the past, in an effort to explain the effects of these agreements in trade. The objective of this study is to develop a model suitable for exploring FTA effects in trade flows in the Mediterranean region. For that purpose, a model is developed for analyzing trade flows based on the family of gravity models; the model parameters are estimated by using a Box – Cox transformation, in an effort to overcome the assumptions of the linear model typically used in similar cases. Results of the derived models are discussed and indicate that transportation costs have a dominant effect in trade; agreement effects are of a lower magnitude and can be negative in cases of specific commodities, whose volume may significantly be affected by other, external factors, as well as the mode used for transporting them.

**Keywords:** Free Trade Agreements, Mediterranean, Gravity Model, Box-Cox Transformation

## INTRODUCTION

Free trade agreements (FTAs) are forms of trade pacts between countries on a bilateral or multilateral basis; these agreements eliminate tariffs, quotas and other barriers, for a number of goods (if not all), traded between involved partners. The aim of FTAs is to increase trade between countries as a result of the relaxation or removal of existing institutional and economic barriers between them. FTAs have been a tool widely implemented for enhancing trade between countries, with examples such as the North American Free Trade Agreement between the US, Canada and Mexico, the Free Trade Agreement of the Americas (FTAA), the ASEAN FTA between eastern Asian countries and the Euro-Mediterranean Free Trade Agreement (EMFTA). In particular, EMFTA has been EU's instrument for establishing FTAs since the 1995 Barcelona Declaration set the principles for establishing FTAs between the EU and other Mediterranean countries in the years to follow [1], [2], [3]; non-EU Mediterranean countries interested in the agreement are expected to adopt it by no latter that 2010. The interest of the research community in the effects of FTAs to trade has been considerable. For example, all Mediterranean countries will be part of the EMFTA agreement in 2010 and therefore analysis of EMFTA's effects so far is invaluable for examining the agreement's policy and potential. As a result, a large number of existing studies have attempted to model and analyze the effects of FTAs in trade flows and trade in general. In this context, the objective of this paper is to develop a model suitable for exploring EMFTA effects in trade flows in the Mediterranean region. The paper is structured as follows: the next section reviews modeling approaches for analyzing FTA effects. Based on that review, the proposed modeling approach is described in the subsequent sections: the problem, data and model are described and results are discussed. The paper concludes with a summary of the study's findings.

## BACKGROUND

Trade flow modeling in general has been widely discussed in the last three decades; most efforts for expressing and analyzing trade flows have concentrated (a) on simulation models, aiming at replicating that phenomenon and its impacts, and (b) on econometric models, attempting to make predictions based on past, actual performance [4]. Simulation models capture the underlying structure of trade flows (comprising of activities such as production, consumption and transportation) [5], respond to inputs and estimate potential impacts to trade flows. Commonly, input-output (I/O) and generalized equilibrium models have been

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exploited for simulating trade flows with the later having the advantages of calculating trade flows endogenously and incorporating transportation costs in the model [5]. On the other hand, econometric approaches for modeling trade flows have been largely based on the gravity model specification; since its introduction by Timbergen [6] and Linneman [7] the gravity model has demonstrated a considerable empirical robustness in describing trade flows [8], [9]. As reported by Porojan [9], in the last decade, gravity models have been employed in numerous studies for analyzing and assessing trade flows. Indeed, the literature reveals a considerable number of publications, either offering modeling improvements and refinements or attempting to explain policy impacts to trade.

As noted earlier, regardless of the method used, FTA effects in trade have been widely examined in the literature, often with controversial conclusions. Among econometric based studies of the last decade, Endoh [10] found that the Latin American Free Trade Agreement (LAFTA) has exhibited neither trade creation nor trade diversion on trade with Japan. On the other hand, Fukao *et al.* [11] provided evidence of some trade diversion as a result of the North American Free Trade Agreement (NAFTA). Roberts [12] investigated the potential of a FTA between China and ASEAN countries; he concluded that neither trade creation or diversion were expected. Eger [13] indicated that while FTAs are not expected to have a short-term impact on trade volumes, a considerable long-run trade creation is anticipated; he reported a 15% long-term increase for NAFTA members. An analysis of trade agreements in African countries (COMESA, ECCAS, ECOWAS) by Musila [14] did not find any considerable impacts in trade diversion and creation; similar conclusions were drawn for the COMESA by Rojid [15] and for the AGADIR agreement by Peridy [16], as a result of the lack of trade complementarity between AGADIR member countries. Tang [33] examined the effects of the NAFTA, ANZCER and ASEAN FTAs and reported that trade within member countries has increased, ANZCER FTA has resulted in trade diversion from non-members and ASEAN FTA has led to a trade increase with non-members (something that has not been observed for NAFTA). Peridy [17] investigated trade effects of the Euro-Mediterranean FTA (EMFTA); he reported that the FTA resulted in an increase of Mediterranean countries' exports to the EU by 20%-27%, indicating trade creation and accounted for the large EU share of Mediterranean exports. Carrere [18] concluded that *"...regional trade agreements generate a significant increase in trade between members, often at the expense of the rest of the world"*. Lee and Park [19] proposed new FTAs for East Asia; they noted that trade facilitation enhances trade creation between FTA members and reduces trade diversion among them and indicated that their proposed FTAs would be beneficial compared to existing conditions. Kalijaran [20] reported that Australia is expected to have more gains of its potential exports because of the IOC-ARC agreement.

As for simulation approaches, in a mid-1990s study, Breston *et al.* [21] simulated a potential trade agreement between EU and Russia and concluded its infeasibility if no other CIS countries were included in the same agreement. Venditto [1], examined the practicability of EMFTA and reported that its benefits were uncertain, expected to be obtained in the long run and did really modify existing relationships between countries. On the contrary, another two studies on EMFTA effects by Augier and Gasiorek [22], [23] indicated a substantial impact on non-EU member countries, especially in production and welfare. McQueen [2] investigated the FTAs between EU and developing countries; he reported significant potential gains for EU but less clear benefits for the partner countries, as a result of limited product coverage and rules of origin. Francois *et al.* [24] arrived at the same conclusions with McQueen [2]. The FTA of the Americas (FTAA) was analyzed by Brown *et al.* [25] using a CGE model. The authors found that (a) FTAA increases the economic welfare of members (with the largest share to the USA) and (b) FTAA is trade diverting for non-members. Finally, Siriwardana [26] investigated the FTA between Australia and the USA and reported growth in exports between the two countries.

## FTA IN THE MEDITERRANEAN REGION

The EU has been pursuing trade agreements with non-member Mediterranean countries since the mid 1950s; early agreements between the former European Economic Community and Morocco, Algeria and Tunisia were established in the treaty of Rome, in 1957 [3]. Few years later (1960), the EFTA agreement was initiated, ensuring free trade between EC members. Only in the early 1990s though, the EU commenced a comprehensive trading policy in the Mediterranean area which resulted in the Barcelona Declaration, in 1995; that declaration set the principles for developing FTAs between the EU and other Mediterranean countries in the years to follow [1], [2], [3]. The instrument introduced for achieving these objectives was the Euro-Mediterranean Free Trade Agreement (EMFTA), which is expected to be fully adopted by the EU and other

interested Mediterranean countries by 2010. An update of the status of EMFTA agreements up until the early 2000's is given by McQueen [2]; most south Mediterranean countries have adopted the EFMFTA agreement by the early 2000s. Mediterranean countries should enter the EMFTA agreement by 2010 and for that reason the analysis of the already established FTAs and their effects to trade flows is invaluable for examining the actual impact of the EMFTA policy so far, along with its potentials for the years to come. Based on the review results, gravity models are widely used for examining FTA effects; in this study such a specification is used for the case of the Mediterranean region, to capture the effects of the EMFTA agreement in trade between potential EMFTA partners.

## MODEL SPECIFICATION

While being largely empirical, gravity models have been successfully used in the past for describing trade flows. Their concept is based on Newtonian physics; trade between two partners is affected by their sizes and proximity [9]. In particular, a flow of goods  $F_{ij}$  between two areas  $i$  and  $j$  is expressed as a function of the characteristics of the origin ( $O_i$ ) and the destination ( $D_j$ ) and some measure of impedance between them ( $R_{ij}$ ):

$$F_{ij} = O_i \cdot D_j \cdot R_{ij} \quad (1)$$

Equation (1) can be modeled as a linear function by taking its logs:

$$\log F_{ij} = \beta \cdot X + \varepsilon, \quad \varepsilon \sim N(0, \sigma^2) \quad (2)$$

where

$X$ : Vector containing the logs of explanatory variables

$\beta$ : Vector of parameters to be estimated

$\varepsilon$ : error term

Typically, explanatory variables include proxies for the sizes of the economies of the two partners (for example GDP, population etc), and their proximity (distance, transportation cost and other barriers to trade). Based on the state-of-the-art review, the modeling needs of the study and data availability, the specification used analyzed in this paper is of the following form:

$$\log F_{ijc} = a_0 + a_1 \cdot \log TE_{ic} + a_2 \cdot \log TI_{jc} + a_3 \log TF_c + a_4 \cdot GAFTA + a_5 \cdot AGADIR + a_6 \cdot EU + a_7 \cdot EMFTA + a_8 \cdot \log TC_{ij} \quad (3)$$

where

$i$ : Origin

$j$ : Destination

$c$ : Commodity ( $c=1,2,3,4,5$ )

$F_{ijc}$ : Flow of commodity  $c$  between origin  $i$  and destination  $j$

$TE_{ic}$ : Total exports of commodity  $c$  from origin  $i$

$TI_{jc}$ : Total imports of commodity  $c$  by destination  $j$

$TF_c$ : Tariffs for commodity  $c$

$TC_{ij}$ : Transportation cost between  $i$  and  $j$

$GAFTA$ : Dummy variable indicating a GAFTA agreement between  $i$  and  $j$

$AGADIR$ : Dummy variable indicating an AGADIR agreement between  $i$  and  $j$

$EU$ : Dummy variable indicating an EU/EEA agreement between  $i$  and  $j$

$EMFTA$ : Dummy variable indicating an EMFTA agreement between  $i$  and  $j$

$a_0, \dots, a_8$ : Model coefficients

As mentioned earlier, commodities are grouped in five categories, namely 1 to 5. Total exports and imports for each commodity act as mass variables, indicating the supply and demand for that commodity and therefore the attraction between the origin and the destination of the flow. Transportation costs, tariffs and existence of trade agreements on the other hand quantify the friction anticipated to be experienced for the flow of commodities between  $i$  and  $j$ . It has to be noted that while the different gravity models found in the literature exhibit a variety of explanatory variables, this paper focuses on selecting those factors that can capture the free trade agreement effects between two countries.

## DATASET DEVELOPMENT

A necessary step towards developing the model was to construct an appropriate dataset for the Mediterranean region. A dataset including data for all 48 EMFTA participants (EU member states and other partners) was set up for the years 1992-2006 (the EMFTA process was initiated in 1995). Participating countries were aggregated into 21 zones, shown in Figure 1 (blue boundaries); aggregation was necessary to reduce estimation of transportation costs and therefore modeling efforts into an acceptable level. The SITC3 commodity classification was adopted. Again, in order to reduce modeling efforts without compromising forecasting reliability, the ten Standard International Trade Classification (SITC3) 1-digit classes have been grouped into five macro-classes, presented in Table 1. Aggregation of classes aimed at producing homogeneous macro-classes and balancing the number of records among those classes.



FIGURE 1  
EMFTA zones considered in the study

TABLE 1  
SITC aggregation into macro-classes

SITC3 1-digit code	Product Description	Macroclasses
0	Food and live animals	1
2	Crude material ex food/fuel	2
5	Chemicals / Products n.e.s.	2
3	Mineral fuel / lubricants	3
6	Manufactured goods	4
7	Machinery / Transp equipment	4
8	Miscellaneous manuf arts	4

Trade flows between zones are the model's dependent variables, expressed in US \$, for a single year and a given commodity group. The COMTRADE database was exploited for that purpose (<http://comtrade.un.org/>). COMTRADE provides both import and export data for each pair of countries. Import and export values are usually different for a number of reasons, the main being the fact that exports are usually recorded *fob* (free-on-board) while imports are recorded as *cif* (cost, insurance and freight). Moreover, imports are usually recorded more accurately than exports because since only the former generate tariff revenues. For that reason,

in the dataset analyzed, import values are used for trade flows. The geographical and commodity classification coverage provided by the COMTRADE database is satisfactory for the European Countries and sufficient for the remaining.

In the gravity model mass variables are expected to capture the impact of the magnitude of origin and destination zones in explaining the related trade flows. GDP values are normally used for this purpose and therefore, for each of the 48 countries within the study area, such information has been collected with the main sources being the EUROSTAT, the Arab Monetary Fund and national statistics bureaus. All GDP data are expressed in US \$. Moreover, for modeling purposes, it is worth exploring to what extent a more proper choice of the mass variables can increase the model goodness-of-fit. In detail, it seems natural to adopt the total import and the total export trade of a zone as mass variable respectively of trade destination and origin. Therefore such variables have been also included into the estimation database.

The basic impedance variable adopted is the generalized cost for transporting goods between zones. A typical proxy for transportation costs used in relevant studies is distance between zone centroids; however in this study detailed transportation costs and tariffs are explicitly used. Tariffs were extracted from the TRAINS database ([www.unctad.org/Trains](http://www.unctad.org/Trains)); the database included three types of tariffs:

- MFN (*most favored nations*): those are the nominal tariffs applied by World Trade Organization member states to other countries, unless preferential agreements are in force;
- PRF (*preferential rates*): usually lower than MFN tariffs, represent the tariffs nominally applied among countries with preferential agreements in force;
- AHS (*effectively applied tariffs*): when available, they denote the tariffs effectively applied to trade between two countries.

Tariffs can be expressed as percentage of the value of the imported goods or calculated by complex rules, for instance an increasing-by-step tariff (i.e. zero tariffs for trade up to a certain volume threshold and then tariffs increasing with trade volume itself). Furthermore, non ad-valorem tariffs can be applied as well, for instance related to the quantity of the good imported. The WITS TRAIN database allows overcoming this issue by considering an ad-valorem equivalent (AVE) tariff, which turns each type of non ad-valorem tariff in a corresponding ad-valorem equivalent. For the dataset of the study, the AVE tariffs for the lowest between MFN, PRF and AHS have been taken into account and tariffs were expressed as percentages of the traded value. With respect to commodity aggregation, tariffs were weighted for each commodity subgroup, using the corresponding subgroup trade volume as weight.

A detailed transportation cost process was adopted; this is described in detail in [27]. For each pair of geographical entities, i.e. NUTS2 zones for European countries and national level for the remaining countries, travel times and costs are available for road, rail (traditional and combined) and shipping (Ro-Ro and containerized) modes. Zones for estimating the transportation costs are indicated in Figure 1 with green boundaries. In brief, based on available data and past research results, detailed transportation cost functions were developed, for calculating transportation costs of shortest paths between entity centroids. These were later weighted with each entity's GDP in order to provide transportation costs between demand zones. A detailed description of the transportation costs is provided in [28].

Free trade agreements in the study area were captured with the use of dummy variables; the agreements explicitly considered in the model were the European Union membership and the EFTA and EMFTA agreements already in existence in the Mediterranean. Regarding the EFTA agreement, for years from 1992 to 1994 it has been set equal to one for the following group of countries: Austria, Finland, Iceland, Norway, Sweden and Switzerland. Some of these countries joined EU in 1995 and therefore, since that year EMFTA dummy has been set in force only between Iceland, Norway and Switzerland. In conclusion, the structure of both aggregated and disaggregated database consists of the following fields: reporting zone (i.e. the destination of the flow), partner zone (i.e. the origin of the flow), year, commodity class, trade value (\$000), tariffs (weighted average by commodity), dummy EFTA agreement, dummy EU/EEA agreement, dummy EMFTA agreement, reporting zone total GDP, partner zone total GDP, reporting zone total imports by commodity, partner zone total exports by commodity, transportation costs.

## MODEL ESTIMATION TECHNIQUE

As previously discussed, the goal of the present paper is to examine the relationship between trade flows, attraction and impedance variables. To date, such investigations have been performed in either of two ways;

with the use of linear regression, or with the use of neural networks. While such investigations have yielded results that are quite satisfactory, they suffer in that when neural networks are used only *predictions* of the dependent variable (i.e. total trade value between two regions) can be made; that is, there can be no meaningful inference regarding the underlying relationship between trade flow and exogenous factors (independent variables) and, as such, policy implications cannot be extracted. Further, when linear regression is used, the implicit hypothesis is made that the underlying function is linear-in-the-parameters; this is a hypothesis that can be, neither theoretically nor empirically, justified. To overcome these apparent shortcomings, the present paper develops a Box-Cox regression model. In essence, the Box-Cox methodology is used as a method of generalizing the linear model; the basic transformation is [29]:

$$x^{(\lambda)} = \frac{x^\lambda - 1}{\lambda} \quad (4)$$

In a regression model, this transformation could be done conditionally, where for a given value of  $\lambda$ , the model becomes

$$y = a + \sum_{k=1}^K \beta_k x_k^{(\lambda)} + \varepsilon \quad (5)$$

This transformation leads to a linear regression that can be estimated via least squares [30]. Basic model theory allows for each regressor to be transformed by a *different value of*  $\lambda$ , but this level of generality becomes excessively cumbersome; as a result,  $\lambda$  is assumed to be the same for all variables in the model. If  $\lambda$  in Eq. (5) is considered an unknown parameter, then the regression becomes *nonlinear-in-the-parameters*. And, although no transformation will reduce it to linearity, nonlinear least squares are straightforward. As a general rule-of-thumb,  $\lambda$  is typically between  $-2$  and  $2$ . Interestingly, when  $\lambda$  equals zero and using L'

Hospital's rule,  $\lim_{\lambda \rightarrow 0} \frac{x^\lambda - 1}{\lambda} = \ln x$ . To obtain the values of  $a, \beta, \lambda$  from Eq. (5), right-hand side derivatives of this equation (with respect to these parameters are needed); these are given as

$$\begin{aligned} \frac{\partial h(\cdot)}{\partial a} &= 1, \\ \frac{\partial h(\cdot)}{\partial \beta_k} &= x_k^{(\lambda)}, \\ \frac{\partial h(\cdot)}{\partial \lambda} &= \sum_{k=1}^K \beta_k \frac{\partial x_k^{(\lambda)}}{\partial \lambda} = \sum_{k=1}^K \beta_k \left[ \frac{1}{\lambda} (x_k^\lambda \ln x_k - x_k^{(\lambda)}) \right] \end{aligned} \quad (6)$$

Of course, it needs to be noted that, from a practical perspective, the parameters of the nonlinear model are not equal to the slopes with respect to the variables, as is the case in regression. As such, the slopes (or equivalently the marginal effects and elasticities) can be given as [31]:

$$\begin{aligned} \ln y &= a + \beta \left[ \frac{x^\lambda - 1}{\lambda} \right] + \varepsilon \\ \frac{d \ln y}{d \ln x} &= \beta x^\lambda = \eta \end{aligned} \quad (7)$$

The extension of Eq. (5) to include a transformation of the dependent variable ( $y$ ) as well as a transformation of the independent variables is rather straightforward and can be given as

$$y^{(\theta)} = a + \sum_{k=1}^K \beta_k x_k^{(\lambda)} + \varepsilon$$

or

$$y^{(\theta)} = \beta' \mathbf{x}^{(\lambda)} + \varepsilon \quad (8)$$

Again, this form includes the linear and log-linear functional forms as limiting cases. Allowing  $\theta$  to differ from  $\lambda$  increases the flexibility of the model. Nevertheless, for clarity of presentation, it is assumed

here that these two values are equal. Further, assuming that  $\varepsilon \sim N(0, \sigma^2)$ , then the log-likelihood for a sample of  $n$  observations can be written

$$\ln L = -\frac{n}{2} \ln(2\pi) - \frac{n}{2} \ln \sigma^2 + (\lambda - 1) \sum_{i=1}^n \ln y_i - \frac{1}{2\sigma^2} \sum_{i=1}^n (y_i^{(\lambda)} - \beta' x_i^{(\lambda)})^2 \quad (9)$$

The maximum likelihood estimator of  $\sigma^2$  will be the average squared residual, making the last term of Eq. (5)  $-n/2$ , collapsing the log-likelihood into:

$$\ln L = (\lambda - 1) \sum_i \ln y_i - \frac{n}{2} [\ln(2\pi) + 1] - \frac{n}{2} \ln \hat{\sigma}^2 \quad (10)$$

### Model Results

The dependent variable considered in this estimation includes the total value of the trade between pairs of regions for four commodity categories; commodities are categorized as (a) food and live animals, (b) crude material (except fuel) and chemical products, (c) mineral fuel and lubricants and (d) various manufactured goods. In this way, it is possible to examine numerous parameters (such as total import and export trade between the regions, transport cost and tariffs and the effect of trade agreement on total values) that might have a significant effect on various trade flow categories. Results are presented in Table 2:

TABLE 2  
Box-Cox Gravity Model Parameters

Model Specification	Commodity Class			
	1 <sup>b</sup>	2 <sup>c</sup>	3 <sup>d</sup>	4 <sup>e</sup>
Explanatory variables	Coefficient ( <i>t</i> -statistic)	Coefficient ( <i>t</i> -statistic)	Coefficient ( <i>t</i> -statistic)	Coefficient ( <i>t</i> -statistic)
Total Commodity Imports	0.557 (21.93)	0.509 (22.651)	1.819 (7.578)	3.755 (5.988)
Total Commodity Exports	0.661 (28.557)	0.741 (36.433)	1.628 (8.080)	4.38 (6.116)
Tariffs	-0.522 (-1.817)	-0.625 (-1.705)	-0.500 (-1.975)	-0.29 (-1.637)
Transport Costs	-1.353 (-5.208)	-1.475 (-5.638)	-3.918 (-6.645)	-1.685 (-3.752)
EU/EEA agreement	ns	-1.068 (-4.628)	ns	ns
EMFTA agreement	-1.331 (-4.312)	-0.813 (-3.865)	0.4422 (1.912)	0.597 (2.671)
$\lambda^f$	1.895 (21.41)	1.789 (21.125)	1.684 (22.270)	1.895 (20.515)
$\theta^f$	2.01 (3.17)	1.14 (3.3650)	$\lambda = \theta$	$\lambda = \theta$
$\rho^2$	0.51	0.32	0.61	0.35

<sup>a</sup> Estimated using Box – Cox transformation

<sup>b</sup> Food and live animals

<sup>c</sup> Crude material (except fuel) and chemical products

<sup>d</sup> Mineral fuel and lubricants

<sup>e</sup> Various manufactured goods

<sup>f</sup> Parameters from Eq. (4)

Based on these results, three important observations regarding the estimated models can be made:

- It can be observed that for most models statistically significant results are obtained; that is, there are independent variables whose influence on the dependent variable is important and are, by and large, consistent with the general directions of previous findings in the literature.
- In total, four separate models were estimated, each corresponding to a different category of goods; Box-Cox transformations were required for both the dependent and independent *in all four models*. However, for the first two models, the  $\lambda$  and  $\theta$  parameters are different, while for models three and four, both the dependent and independent variables were transformed by the same Box-Cox parameter. It must be noted

that both parameters ( $\lambda$  and  $\theta$ ) were allowed to be different from one only when a likelihood ratio test suggested this to be statistically acceptable.

- All models offer a rather good fit to the data.  $\rho^2$ , the nonlinear equivalent of  $R^2$  in linear regression, takes on values ranging from 0.32-0.61 which is considered to be good fit for nonlinear models.

According to Table 2 results, total commodity exports and imports have a strong positive correlation with trade flows for all commodity categories; this is expected since these variables are direct representations of the demand and supply for each commodity type. Therefore, their selection instead of proxies such as the GDP is justifiable. Tariffs seem to have an impact on trade flows of commodity categories, particularly on categories 1, 2 and 3. Their negative sign is expected since tariffs pose a barrier to trade; however in all cases their impact is low. A possible explanation is the existence of FTAs; large part of the dataset covers a period and set of countries already participating in such agreements or custom unions (the EU). As a result, such barriers are gradually eliminated and play a lesser significant role in trade flows.

Transport cost impacts are negative and high in most cases; similarly to other studies examining the EMFTA agreement [16], [32], transportation costs have a considerable impact in flows. The EMFTA agreement has an impact to all five commodity categories; interestingly that impact in the cases of commodity categories 1 and 2 is negative. This is probably due to the particular nature of the goods within those commodities, grouping mainly crude material and mineral fuel: it is well known that the trade volume of such commodities strongly depends on external factors highly variable in small time periods. Therefore, the possibility that the EMFTA agreements were put in force in a period of decreasing trend in trade implies that the model captures this trend through a negative sign of EMFTA agreements for those commodities. From one side, this would suggest introducing for those commodities further explanatory variables within the model specification. However, those commodities make mainly use of very specific transport modes (e.g. pipelines) and therefore they can be considered as marginal with respect to the demand segments impacting on transport services to be analyzed. Moreover, with respect to category 1, restrictions on food and live animals posed by the EU even through the EMFTA agreement, still pose barriers to trade for these commodities.

## CONCLUSIONS

The objective of this paper was to review modeling efforts for analyzing effects of Free Trade Agreements to trade flows and to develop an econometric model for analyzing the effects of such agreements to trade in the Mediterranean region. An econometric gravity model specification was developed for that purpose and the model parameters were estimated using a Box – Cox approach. Results indicated that transportation costs have a dominant effect in trade; agreement effects are of a lower magnitude and can be negative in cases of specific commodities, whose volume may significantly be affected by other, external factors, as well as the mode used for transporting them. The model is capable of providing useful insights to decision makers regarding the characteristics and details of FTAs in the Mediterranean region.

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